Manual Training Course in Concrete

CONCRETE FOR PERMANENCE

PUBLISHED BY

Association of
American Portland Cement
Manufacturers

Bellevue Court Building
Philadelphia, Pa.

1915

Lessons and General Outline With Suggested Exercises

FOR A

Manual Training Course in Concrete

PREPARED FOR THE USE OF INSTRUCTORS IN PLANNING AND CONDUCTING ELEMENTARY WORK IN CONCRETE

Price, 25 Cents per Copy

Portland cement association, Chicago.

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Preface

Concrete is so extensively used as a material of construction as to make the need for a short general course in elementary and high schools imperative. This has warranted the preparation of a series of elementary lessons and exercises which may be used to stimulate the interest and ingenuity of the younger students, thus widening, at a formative period, their knowledge of cement and the materials used in concrete construction.

The scope of this course is necessarily limited by the time available for presenting such a subject. The Association of American Portland Cement Manufacturers has prepared, from time to time, various bulletins treating of the application of concrete in countless ways, and the instructor may readily enlarge or vary the course by using these bulletins as text-books or guides in the preparation of more extended lectures or problems.

For reference purposes the name, number, and general scope of the bulletins are given below:

No. 10. Concrete Surface Finish.
No. 18. Reinforced Concrete Chimneys.
No. 22. Cement Stucco.
No. 23. Concrete Tanks.
No. 26. Concrete in the Country.
Factories and Warehouses of Concrete.
The Concrete House and Its Construction.
Concrete Highways.
Facts Everyone Should Know About Concrete Roads.
Standard Methods of Testing and Specifications for Cement.
Lessons, General Outline, and Suggested Exercises for a Manual Training Course in Concrete.
Concreting in Winter.
Short-span Concrete Bridges.
Single Track Streets and Dished Alleys.
A Concrete Country Road.
Maintenance of Concrete Roads and Streets.
Standard Recommended Practice in Concrete Road Construction.
Concrete School Houses.
Concrete Silos.
Concrete Blocks.
Concrete Drain Tile.
Concrete Pipe.

The files of the leading technical papers are replete with articles dealing with the use of cement and concrete for specific purposes. The Proceedings of the American Concrete Institute (Philadelphia) also contain much valuable information. Instructors and students may very readily increase their working knowledge of any phase of concrete construction by consulting these papers and proceedings.

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LESSONS

LABORATORY GUIDE

I. Manufacture of Portland Cement

Cements and limes have been used since the dawn of civilization. The famous Appian Way, the great system of aqueducts and other structures built by the Romans, are to-day in a remarkable state of preservation, and proof positive that they understood the use of cement and concrete.

Notwithstanding the early use of these materials, little was known of their chemistry, and no substantial advance was made in the manufacture of lime and cement from the time of the Romans until 1756, when John Smeaton, who had been employed by the English government to build a lighthouse upon a group of gneiss rocks in the English Channel, near the coast of Cornwall in Devonshire, discovered that an impure or clayey limestone, when burned and slaked, would harden into a solid mass under water, as well as in air. This discovery of Smeaton's seemed to pave the way for rapid improvement and development in the lime and cement industries. In 1796 James Parker, of Northfleet, England, obtained a patent for the manufacture of a cement which he aptly named Roman cement. Parker's process consisted of burning certain stone or argillaceous products called "nodules of clay" in an ordinary lime kiln, and then grinding to a powder. Cement produced in this manner rapidly gained favor among engineers and builders, and resulted in natural cement plants springing up all over the continent of Europe, England, and later, about 1818, in the United States. In 1824 Joseph Aspdin took out a patent in England for the manufacture of an improved cement, produced by calcining a mixture of limestone and clay. To the resulting powder he gave the name of "Portland Cement," because, when it hardened, a yellowish-gray mass was produced, resembling in appearance the stone found in various quarries on the isle of Portland off the south coast of England. To Joseph Aspdin, therefore, is given the credit of making the first Portland cement, and he is generally recognized as the father of the modern Portland cement industry.

In this country the cement industry began with the discovery, in 1818, of a natural cement rock near Chittenango, Madison County, New York, by Canvass White, an engineer on the Erie Canal. In 1825 cement rock was found in Ulster County, New York, along the Delaware and Hudson, and in 1828 a mill was built in Rosendale, New York, and it was from this place that the natural cement obtained its name. Other canals along which cement rock was discovered, with location and date, are: Illinois & Michigan Canal, at Utica, Ill., in 1838; James River Canal at Balcony Falls, Va., in 1848; and Lehigh Coal & Navigation Co. Canal at Siegfried, Penna., in 1850.

In the spring of 1866 D. O. Saylor, Esaias Rehrig, and Adam Woolever, all of Allentown, Penna., formed the Coplay Cement Co. and located near Allentown. Mr. Saylor was president and superintendent of the mill. Early in the seventies he began experimenting on Portland cement from the rock in the quarries. Noticing that although the harder burned portions of his Rosendale clinker gave a cement which in a short period of time would show tensile strength equal to the best European Portland cement, it soon crumbled away. He decided that this was because the raw material was not properly proportioned. The result of these experiments taught him to mix his high-limed cement rock and low-limed cement rock in the correct proportions, and after many experiments and trials true Portland cement was produced in 1875. This was the first Portland cement made in the Lehigh district and probably in the United States.

Knowing how to produce a high-grade Portland cement was not all that was necessary. The next difficulty encountered was the sale of it. This new American Portland cement was manufactured at a high cost; therefore it could not be offered at a lower price than the imported article, and it was only by aggressive methods that Mr. Saylor secured a market for his product, which amounted to only 1700 barrels a year.

About the same time Thomas Millen was constructing a plant at South Bend, Ind., and plans were soon under way at Wampum, Penna., Kalamazoo, Mich., and Rockford, Me., for other mills.

This, then, was the small beginning of the American Portland cement industry, which has grown from a production of about 83,000 barrels in 1880, and less than 1,000,000 in 1895, to the total of approximately 92,000,000 in 1913.

This brief history of the development of the industry prompts the question, "Just what is Portland cement?" This is probably answered by the definition given in the "Standard Specifications for Portland Cement" adopted by the American Society for Testing Materials. This definition is quite formidable, consisting, as it does, of long phrases and equally long words, and, in order to be understood, will undoubtedly require some explanation.

"Portland cement is the term applied to the finely pulverized product resulting from the calcination to incipient fusion of an intimate mixture of properly proportioned argillaceous and calcareous materials, and to which no addition greater than 3 per cent. has been made subsequent to calcination."

This definition gives, in addition to the composition, an outline of the process of manufacture, but not in the order taken in manufacture. These several points in their natural order would be as follows:

First—that Portland cement is composed of calcareous and argillaceous materials.

Second—that the raw materials must be properly selected and prepared for the process of manufacture, due regard being given to proper proportioning.

Third—that there must be an intimate mixture of the raw materials. This necessitates the drying, fine grinding, and thorough mixing of the raw materials.

Fourth—that the raw material or mixture must be burned to a clinker and that the heat must be such as to cause a partial melting of the ingredients.

Fifth—that the finished product, or Portland cement, is the product obtained by grinding this clinker to a powder.

The last clause in the definition provides for the addition of a small amount of some material to regulate the setting time, but limits the quantity to prevent adulteration.

The principal elements or compounds in Portland cement are lime (CaO), silica (SiO_2), and alumina (Al_2O_3), but a small percentage of oxide of iron (Fe_2O_3) and magnesia (MgO) is also contained.

The composition of a standard Portland cement is usually within the following limits:

Compounds	Per Cent. Limits
Silica (SiO_2)	20 to 24
Alumina (Al_2O_3)	5 to 10
Iron oxide (Fe_2O_3)	2 to 5
Lime (CaO)	60 to 65
Magnesia (MgO)	1 to 4
Sulphur trioxide (SO_3)	0.5 to 1.75

Nature has provided an abundance of these calcareous and argillaceous materials suitable for the manufacture of Portland cement. The calcareous variety is always in the form of calcium carbonate, such as limestone, chalk, marl, or the precipitated form obtained as a waste-product from the manufacture of alkalis. The argillaceous division includes clay, shale and slate, cement rock, and selected blast furnace slag. Cement is made in this country from all these materials, each plant using one of the calcareous combined with one of the argillaceous materials.

Portland cement may also be divided into classes, according to the method of manufacture, which are as follows:

1. Wet process.
2. Semi-wet process.
3. Dry process.

In the wet process the raw materials are intimately mixed, ground, and fed (in the form of a slurry containing sufficient water to make it of a fluid consistence) into the rotary kilns. In the semi-wet process a similar but drier slurry is used, while in the dry process raw materials are ground, mixed, and burned in the dry state.

Because of the fact that the larger portion of Portland cement manufactured in the United States to-day is made by plants using the dry process, the description of the process of manufacture will be confined to an account of this method.

The manufacture of Portland cement itself is divided into five heads, as follows:

1. Mining and quarrying of raw materials.
2. Drying and grinding.
3. Proportioning and mixing.
4. Burning the mixed materials to incipient fusion.
5. Grinding the clinker thus burned to an extremely fine powder, meanwhile adding the proper proportion of gypsum, the resulting powder being known as Portland cement.

The excavation of the raw materials is the first step toward the actual manufacture of Portland cement, and the one concerning which least has been published. Local conditions enter into this preliminary stage to such an extent that few general statements can be made concerning it. The natural raw materials are worked by one of three general methods. First, quarrying and digging from open pits. Second, mining from underground workings. Third, dredging from deposits covered by water. Inasmuch as this paper deals with the manufacture of Portland cement itself, we will not go deeply into the preparation of the raw material.

The raw materials for the greater part of the Portland cement made in the United States to-day are:

(*a*) Limestone and clay, shale or slag.

(*b*) Cement rock and pure limestone.

The method of quarrying the rocks usually follows that customary in all quarry operations. The rock is dislodged from the quarry face by means of an explosive and then loaded into side dump cars or aërial trams by either steam shovel or manual labor, preferably the former. The stone is then conveyed to the stone house, where it is crushed to comparatively small sizes and then transported to storage-bins before being mixed with the other ingredients. While in storage the stone may be sampled and analyzed. Another method used is to pass the limestone, shale, or cement rock through crushers and ball mills, or other preliminary grinders, from which it is conveyed to storage-bins. The ball mills are cylindrical steel drums containing a quantity of steel balls. The material to be ground, after drying, is continuously added. As the cylinder rotates the balls roll, thus grinding the rocks to coarse grits. The coarse grits are then run into storage-bins. Tube mills which are used further on in the process are similar in general to the ball mills.

Shale, which for practical purposes may be looked upon as solidified clay, is excavated, dried, ground, and then conveyed to storage-bins.

After the raw materials have been drawn from their respective bins and accurately proportioned by weighing, they are delivered to a screw conveyor which completes the mixing and delivers the combined material to the tube mills. The tube mills are revolving cylinders half full of flint pebbles or steel slugs which reduce the material continually being fed into practically the fineness of finished cement. At this point, however, we are a long way from the finished cement, since the product of these mills has a long journey before it is ready for the consumer.

All the tube mills deliver to the same conveyor, which results in a uniform product of the raw material mill as a whole. At frequent intervals samples are taken from the belt and delivered to a sample can which is collected at stated intervals by one of the chemist's assistants. The sample is then taken to the laboratory where tests are made to determine its composition.

From the tube mills the material is fed to the kilns through a system of conveyors. The kilns themselves are from 6 to 8 feet in diameter and from 60 to 150 feet long, 125 feet being the average length. They are lined with fire brick and revolve at about the rate of one revolution per minute. It is estimated that a particle of raw material takes about an hour to traverse the entire distance from the feed to the outlet. Powdered bituminous coal, crude oil, or gas is used as fuel, powdered coal being the one most generally used. It is blown into the kiln at the end opposite that at which the raw materials enter.

The raw material entering as a powder is gradually brought to the point of incipient fusion at a temperature of 2500° to 3000° Fahrenheit, producing clinkers varying in size from ¼ inch up to about 1½ inches in diameter. It may also be mentioned that the clinker is red hot when discharged, but is soon cooled by sprays of water or cold-air blasts which are played over the elevator and also upon the clinker when delivered to the storage piles.

If we go to the front of the kilns, we will see that the method of heating is the same as used in drying slag and limestone, with the difference that considerably more fuel and blast are required as a higher temperature is necessary. By means of smoked glasses experienced workmen are able at all times to note the condition within the kiln.

From the kiln, the clinker may go—(*a*) to the clinker storage pile for later grinding, or (*b*) directly to the grinding department.

Either before or after the preliminary grinding of the clinker by jaw crusher it is usual to add gypsum, either by hand or automatically, in order to retard the setting time of the cement. Were gypsum not added, the cement would harden quickly and develop little strength. Approximately two pounds of gypsum are added to every 100 pounds of clinker. This is controlled by the chemist from analyses of the finished cement and from the setting determinations made hourly in the physical laboratory.

After the gypsum has been added, the material is delivered to the tube mills, which complete the grinding. These tube mills are similar to those which grind the raw material, and are also half full of flint pebbles or steel slugs which rotate and grind one against the other, reducing the cement to the fineness with which every one is familiar. There are also special grinding machines which supplement the tube mills. Frequent samples are taken of the finished product. It is customary to make up test pats every hour and briquettes twice a day, while in the chemical laboratory complete analyses are continually being made of the finished product, as well as of the raw materials which enter into its composition.

The bins used for storage are similar to those used in storing grain. The material is deposited in these bins by means of a conveyor belt with a tripping mechanism which can be run from one end of the house to the other. The cement is drawn out from below through holes in the floor, delivering to screw conveyors underneath. A peculiarity noted in drawing cement or other similar material is that when the drawing is started, the cement comes out as an average of the entire bin. If, for example, only one hole is opened below the bin, the top surface will "cave" slightly after the drawing is continued for a short time, and from then on small portions are observed to fold in from the outside of the crater, indicating that an average of the entire stock is being delivered below. From each of the tunnels conveyors carry the cement to large elevators, which raise it finally to large hoppers above the packing floor, on which are installed packing machines. A cement sack may be filled (when packing machines are used) through the bottom, and not through the top. The bags are tied previous to filling, and a valve may be discovered by careful inspection of any of the standard sacks used to-day. Every modern cement manufacturer employs a packing machine for filling sacks. As sacks are filled a conveyor belt running the entire length of the packing room unloads them within a few feet of the car, ready for shipment.

REFERENCES

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"Materials of Construction," by J. B. Johnson. Published by John Wiley & Sons, New York City.

II. Concrete Aggregates

Present-day success in the use of concrete is not due to any particular "discovery," but is the result of a consistent, scientific study and investigation of the component materials.

As ordinarily employed, the term "aggregates" includes not only gravel or stone, the coarse material used, but also the sand, or fine material, mixed with the cement to form either mortar or concrete. Fine aggregate is defined as any suitable material that will pass a No. 4 sieve or screen having four meshes to the linear inch, and includes sand, stone screenings, crushed slag, etc. By coarse aggregate is meant any suitable material, such as crushed stone and gravel, that is retained on a No. 4 sieve. The maximum size of coarse aggregate depends on the class of structure for which the concrete is to be used.

The strength of concrete can never be greater than that of the materials used as aggregates. Nothing is more conducive to unsatisfactory results in concrete work than poor aggregates. The condition of the cement, methods of mixing, the proportions used, and the amount of water added, also the method of depositing and curing concrete, all have their effect upon its density and strength, but even with the most careful attention given to these details, good results are impossible without good aggregates.

The fact that the aggregates *seem* of good quality yet may be proved *totally unsuitable* shows that study and careful tests are necessary if the best results are to be obtained. The idea that the strength of concrete depends entirely upon the cement and that only a superficial examination of aggregates is necessary, is altogether too prevalent. The man who understands his aggregates, grades them properly, sees that they are washed, if necessary, then mixes them in proportions determined by thorough testing, study, or actual experiences, is the one who will make the best concrete.

In the selection and use of sand more precautions are necessary than for the coarser aggregate, due to its physical condition and a wider variation in properties. A knowledge of these properties and of the method of analysis to determine the suitability of sand for use in mortar and concrete may be easily applied to an analysis of the coarse aggregate. (Stone screenings, broken stone, and gravel will be discussed only where their properties and the methods of examining them differ from those of sand.)

Origin and Composition

Geologists classify rock in one of two large groups:

1. Igneous.
2. Sedimentary.

Igneous Rocks

Igneous rocks are those which have been formed by the cooling of fused material. They are classified either as massive or laminated, according to their structure. The massive igneous rocks are those which have been solidified, undisturbed, from a fused state, and which have not been subsequently subjected to severe external stresses. When the rock was subjected, either during or after cooling, to external pressure, a laminated structure seems to have resulted, with the component minerals arranged in more or less definite alternating bands. Most *granites* and all *trap-rock* belong to the first class, while rocks of the second class are termed gneisses.

Sedimentary Rocks

Sedimentary rocks are those derived from the breaking up or disintegration of preëxisting strata, the material so obtained being carried, usually in suspension or solution, to some point where it is redeposited as a bed of fine particles, clay, or calcareous material, such as shells, marls, etc. Subsequently, this loosely deposited material may become consolidated and compacted by pressure or other agencies, the result being the formation of sandstone, shale and slate, or limestones, dolomites, and marbles.

Sedimentary rocks may be classified on a combined chemical and physical basis, distinguished by the material of which they are chiefly composed, as:

1. Silicious sedimentary or sandstone and conglomerates.
2. Argillaceous or clayey rocks, such as shales and slates.
3. Calcareous rocks, namely, marble, compact limestone, granular limestone, and magnesian limestone, or dolomites.

Sources of Supply

The materials commonly used as coarse concrete aggregate in different places throughout the United States are the sedimentary rocks, which may be grouped into three classes on the basis of origin:

1. Glacial deposits.
2. Coastal plain deposits.
3. Stream deposits.

All these deposits contain more or less silt, clay, loam, or other finely divided impurities.

The gravel beds of the glacial drifts furnish excellent material for concrete. Baker, in "Roads and Pavements," says: "Glacial gravel exists in considerable quantities in western Pennsylvania, in the greater part of Ohio, in northern Indiana, and in Illinois, and to some extent in several of the States of the southwest. There are large areas of this gravel in Wisconsin, Minnesota, and Iowa."

Physical Conditions

Sands differ not only in chemical and mineralogic composition, but in physical condition. They often contain many impurities, and the methods for determining their presence, as well as their effects, should be known.

Impurities

Many of these impurities impair the hardening properties of cement, and hence the strength of the concrete in which used. Much has been written relative to the effect of clay upon concrete, and many contradictory opinions have been advanced. Engineers are, however, fairly in accord on certain conclusions. When clay exists as a coating on the particles of sand aggregate, it is undoubtedly injurious, as proper adhesion between the cement and the sand surfaces is then prevented. When, however, clay of a silicious nature in the form of separate particles exists to a small extent throughout the mass of aggregate, it appears to cause no serious harm in many kinds of concrete work. Clay in this form acts as an adulterant, without seriously reducing the tensile strength of the concrete. Their opinions, however, are based largely on the results of tensile-strength tests on relatively dry mixtures. It is doubtful whether, under field conditions, or even in large compression-test specimens made up in the laboratory, these results would be obtained. An excess of clay tends to lead one into believing that the concrete contains an excess of cement rather than a shortage. The only advantage that can be claimed for the presence of clay is that it increases the density of the concrete by filling some of the voids.

The presence of clay in sand may be detected by the well-known method of rubbing the material between the hands. If clean, the sand should not adhere to or discolor the hands. Also a small quantity of the sand may be stirred or shaken in a tumbler or bottle of water, when the presence of clay will at once be shown by a characteristic cloudiness of the water. Since the clay remains longer in suspension than the sand, it will separate and settle later in a layer on top.

Vegetable Matter

A coating of vegetable matter on sand grains appears not only to prevent the cement from adhering, but to affect it chemically. Frequently a quantity of vegetable matter so small that it cannot be detected by the eye, and only slightly disclosed in chemical tests, may prevent the mortar from reaching any appreciable strength. Concrete made with such sand usually hardens so slowly that the results are questionable and its use is prohibited. Other impurities, such as acids, alkalis, or oils in the sand or mixing water, usually make trouble.

The usual way of determining the quality of sand is to make up briquettes in the proportions of one part cement to three parts of the sand to be tested, and compare the results with the strength of a mortar made with the same cement and standard Ottawa sand in like proportions and of standard consistence. Standard Ottawa sand is exceptionally uniform, and is obtained from Ottawa, Ill.

The presence of moisture in sand may make proper mixing with other materials somewhat difficult, as a uniform distribution of cement in the mortar is hard to obtain.

General Requirements

The quality of concrete is affected by—

1. The hardness, or crushing strength, of the aggregates.
2. Their durability or resistance to weather and abrasion.
3. Grading, or maximum and relative sizes, of particles.
4. Cleanliness or freedom from foreign materials.
5. The shape and nature of the surface of the particles.

Hardness

The hardness of the material grows in importance with the age of concrete. Because of the rounded surface of the aggregate, gravel concrete one month old may be weaker than concrete made with comparatively soft broken stones; but when one year old, it may surpass in strength the broken-stone concrete, because, as the cement becomes harder and the bond firmer, the resistance of the aggregate to stress becomes a more important factor.

The grains should offer at least as high a resistance to crushing as does the cement after attaining its maximum strength. In comparing sands of the same kind, those having the highest specific gravity are likely, as a rule, to be the strongest. This applies in a general way to the comparison of different kinds of rock also.

Value of Different Rocks

Different rocks of the same class vary so widely in texture and strength that it is impossible to give definitely their relative values as aggregate. However, a comparison of a large number of tests of concrete made with broken stone from different kinds of rock material indicates that its value as an aggregate is largely governed by the actual strength of the stone itself, the strongest stone producing the strongest concrete.

Comparative tests discussed by various writers indicate that, in the order of their value for concrete, the different materials stand approximately as follows:

1. Granite.
2. Trap-rock.
3. Gravel.
4. Marble.
5. Limestone.
6. Slag.
7. Sandstone.

The grading, that is, the relative size and quantity of the particles of an aggregate, determines in a large measure the density of the mass, which greatly affects the quality of the concrete. A coarse, well-graded aggregate produces a denser and stronger concrete or mortar. A sufficient quantity of fine grains is valuable in grading the material and reducing the voids, but an excess has a tendency to diminish the compression strength considerably.

Weights and Voids

A high unit weight of material and a corresponding low percentage of voids are indications of coarseness and good grading of particles. However, the impossibility of establishing uniformity of weight and measurement due to different percentages of moisture and different methods of handling makes these results merely general guides that seldom can be taken as positive indications of true relative values. This is especially true of the fine aggregates in which percentages of voids increase and weights decrease with the addition of moisture up to about 6 per cent.

Maximum Size

Within reasonable limits the strength of concrete increases with the size of stones. For mass concrete the practical maximum size is 2½ or 3 inches. In thin reinforced structures, such as floors and walls, the size must be such as can be worked readily about the reinforcing metal, and 1¼ inches is generally the maximum.

Cleanliness

As stated, the particles of rock should be free from dirt and dust, and should not be used when even partly covered with clay; such impurities prevent the cement from obtaining a bond on the surface of the particles, and often contain materials which retard the hardening of the mortar or concrete and prevent it from acquiring normal strength within a reasonable length of time.

An excess of clay or dirt in any form also affects the color of the concrete when hardened, and necessitates more thorough mixing.

Shape of Particles

The shape of the rock particles influences the strength of the mortar or concrete. Flat particles pack loosely and generally are inferior to those of cubical fracture.

Analysis

The chief value of an analysis of any sand results from the comparison of its various properties with those of other sand tested under similar conditions and recognized as of a good quality.

Classification

The sands in common use as aggregate throughout the United States are sedimentary, hence the classification can usually be confined to the degree of consolidation and the kind of material, on the basis of whether its formation is chiefly siliceous or calcareous. Hardness and texture are ready aids in these determinations, which may be conducted in an elementary manner.

The natural sands are usually siliceous, but they vary in degree of consolidation, which determines in a large measure the crushing strength and durability of the concrete. Their durability is also dependent upon the nature and amount of impurities present, as feldspar, mica, oxides of metals, etc. Such impurities account largely for the variegated coloring in sand grains.

Specific Gravity

As sands or rocks of the same kind and having the highest specific gravity are likely to be strongest, a determination of the specific gravity of different sands is valuable, since it is a ready indication of the nature and hardness of the material. As a rule, sand having the highest specific gravity, other things being equal, will give the best results.

The specific gravity of a material is determined by dividing its weight by the weight of the water which it displaces when immersed. Take a convenient amount of sand, screen it through a ¼-inch screen, dry, and weigh. Then place some water in a glass graduate, read the height of the water, add the sand, and again read the height of the water. The difference in readings will be the amount of water displaced by the sand. Divide the weight of this water into the weight of the sample of sand. The result will be the specific gravity of the sand. (For detailed methods of testing sand and cement-sand mortar, Bulletin No. 33, of the United States Bureau of Standards, should be referred to.)

Determinations Necessary

Physical Analysis.—The determinations necessary for a good physical analysis of sand are:

1. Strength and density in mortar.
2. Gradation and effective size of grains.
3. Cleanliness, including per cent. and nature of silt.
4. Percentage of voids.

Density

In the study of sands, a determination of their density is important as regards both quality and economy. Other physical conditions being equal, the sand which produces the smallest volume of plastic mortar when mixed with cement in the required proportions makes the strongest and least permeable mortar, and the densest mortar will be the strongest. This requires that the sand be graded from coarse to fine, the coarser particles predominating. (The question of determining density will be discussed in the lesson on Proportioning, Mixing, and Placing.)

Gradation and Effective Size

Sand in which coarse grains predominate will produce a greater strength in mortar than that made up of fine grains, because it presents a more compact mass, as well as a smaller amount of surface area to cover with cement, and usually a smaller percentage of voids. A fine sand requires more thorough mixing than coarse sand in order to get a proper distribution of cement.

The size of sand grains is so important that it is often profitable to ship a coarse sand a considerable distance rather than use a local fine sand. Feret, the French authority, computed that it was more economical to use coarse instead of fine sand, even though the cost is several times as great. It does not follow, however, that because coarse particles have the smallest area per unit of volume, the aggregate should all be large. Particles of the same size form a volume having a larger percentage of voids than if graded in size, hence requiring a larger proportion of cement to produce the maximum strength.

Granulometric Composition

The determination of the granulometric composition or mechanical analysis of sand is made in order to study its properties and to judge of its value compared with other sands, and, if necessary, regrade its grains so that a denser mass may be secured.

That the strength, quality, and value of a sand may be indicated by ascertaining whether the majority of its particles are coarse, medium, or fine has been generally established, and it is also important to determine the relative degree of coarseness and fineness.

The percentages of different size grains are frequently determined by a mechanical analysis. The sample is first screened through a number of sieves of successive sizes, and the percentage by weight retained on each recorded.

For this work the following sieves are recommended:

Commercial No. of Sieve
4
10
20
30
40
50
80
100
200

A standard sieve is made of woven brass wire, set into a hard brass frame, 8 inches in diameter and 2¼ inches deep. These sieves are described by numbers corresponding approximately to the number of meshes per linear inch.

All material referred to as sand must pass a No. 4 sieve. Not more than 20 per cent. should pass a sieve having 50 meshes per linear inch, and not more than 5 per cent. should pass a sieve having 100 meshes per linear inch.

The tabulated results showing the percentages by weight retained on the different sieves form a valuable basis for a study of the effective sizes of grains, and for comparison with other sands whose value in mortar or concrete has already been determined.

Cleanliness

The effect of dirty sand is dependent upon the quantity and nature of the impurities and the form and manner in which they are present. The manner in which silt is contained in sand may be determined by inspection. The silt in a sand is that material which in solution and in suspension is carried away in wash-water so applied as not to remove the small grains of sand. This amount may be ascertained by determining either the amount of substance contained in the wash-water or the amount of loss sustained by the sand through washing. The latter method is more generally used.

If the silt is vegetable matter in a gelatinous or viscous state, forming a colloidal covering over the surface of the sand grains, its presence may be determined by immersing the material in a dilute solution of sulphuric or hydrochloric acid and comparing the strength of cement mortar made from the sand before immersion and after the sand has been treated with the dilute acid and thoroughly cleansed by washing.

Voids

Voids are air-spaces between the grains and are usually referred to as a percentage of the whole. A sand consisting of grains all uniform in size will present the maximum of voids. This can be illustrated as follows: Perfect spheres of equal size piled in the most compact manner leave, theoretically, but 26 per cent. of voids. The only requirement is that the spheres be of equal size. Suppose, now, that the spaces between such a pile of equal-sized spheres were filled with other perfect spheres of diameter just sufficient to touch the larger spheres, the voids in the total included mass would be reduced theoretically to 20 per cent.; and should this be followed up with smaller spheres, the air-spaces or voids could be reduced sufficiently to make the mass water-tight. Practically, however, a mass of equal-sized spheres will be found by experiment to contain about 44 per cent. voids, which may be reduced as indicated above. The shape of the particles also affects the percentage of voids. Round particles compact more readily and firmly and with less difficulty than angular particles.

Conclusion

The scope of concrete work has become so great that it demands a nation-wide study of aggregates. But such study alone will not solve all the problems and insure good work in the future. It will, however, serve to give an idea of the relative merits of the various aggregates available. We now have standard specifications which demand certain requirements from the cement manufacturers. How much more do we need standard specifications for the selection of concrete aggregates? The preceding paragraphs have, in a brief way, given you some idea of the properties required in good aggregate, which are, briefly, good grading, cleanliness, and durability. Therefore, with good aggregates, standard Portland cement, and careful and efficient workmanship, good concrete can easily be obtained.

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III. Proportioning, Mixing, and Placing of Concrete

I. Proportioning

Theory

In order to comprehend the importance of correctly proportioning the ingredients used in the making of concrete we must in the beginning obtain a correct idea of the theory of the material we propose to manufacture.

The aggregates consisting of sand and gravel or broken stone are wholly inert until combined with Portland cement. Consequently it is of prime importance that every piece of coarse aggregate be thoroughly surrounded with sand-cement mortar and that every grain of sand be inclosed in a film of neat cement. In so far as actual practice departs from this fundamental principle, just so far will the bonding be defective.

The second important principle of concrete composition is that voids shall be eliminated by such gradation of materials that the spaces between larger pieces of the coarse aggregate will be occupied by smaller pieces, and the spaces between these will in turn be filled by sand until in a perfectly proportioned mixture there will remain only such voids as will be taken up by the cement paste when the concrete is finally compacted in the place of its ultimate use. The absolute elimination of voids is an ideal condition, hence it is essential to use every means in our power toward approaching the perfection suggested. The more nearly we approximate the theoretical possibility, the more successful we shall be in actual practice.

Object

Both strength and density in finished concrete construction are dependent upon careful proportioning. A very porous concrete may, under certain conditions of manufacture, be stronger than a seemingly dense concrete which is lacking in cement or in coarse aggregate. Hence we observe work disintegrate after two or three years, and upon examining a fracture find that the concrete has no large voids, but is composed of fine sand with little or no coarse aggregate. Such material may appear dense, but hardly deserves to be called concrete.

On the other hand, remarkable instances of strength developed in porous concrete may be observed where the coarse aggregate was fairly well graded and but little sand used. This practice is not recommended because the working conditions might not be identical, and a concrete possessing a large percentage of voids will not be water-tight. The point is mentioned merely to emphasize the fact that coarse aggregate and cement give strength to concrete. Sand increases the density.

Impermeability, or resistance to the passage of water, is one of the most prominent characteristics of good concrete and is absolutely dependent upon the elimination of voids, which results only from correct proportioning of ingredients. A porous concrete is never water-tight. Quite a number of processes for waterproofing have been suggested; some, like soap and alum, or the "Sylvester Process," are public property, while others are either secret formulas or process patents. Some consist of incorporating compounds in the concrete at the time of mixing, and others of applying compounds to the exterior or interior of the work after completion. If the concrete is properly proportioned, there is no reason for using any integral waterproofing medium.

In reinforced concrete work a satisfactory bond between the steel and concrete can be obtained only by such careful proportioning as will insure a concrete practically free from voids. This does not mean merely slushing in water enough to fill spaces between aggregate surrounding rods or other reinforcement. Surplus water will disappear by evaporation, leaving cavities adjacent to the reinforcement, and when a failure occurs, rods will be found pulled out of porous concrete, the porous concrete not offering sufficient bond to transfer the stress to the steel reinforcement.

Methods of Proportioning

One method of proportioning is by measuring the amount of water required to fill the voids in the coarse aggregate, and using a like proportion of sand, in turn measuring similarly the voids in the sand to determine the required proportion of cement. This method of proportioning is inaccurate and cannot be recommended for general use.

Another method consists of ascertaining the specific gravity of the material to be used, then weighing a fixed volume of the sand, gravel, or broken stone in the condition in which it is to be used, and from the difference between the weight of like volumes of solid and loose material determining the percentage of voids. This method is scientifically correct, but will seldom be used outside of laboratory practice on account of the equipment required to make the computation accurately.

There is no doubt that density proportioning is the most practical and definite method yet evolved. While it is largely a cut and try method, and should be checked by cylinder compression tests, there are fewer possibilities of error and the results are not dependent on the use of delicate apparatus. The density test has its value in the determination of the proper amount of coarse aggregate to use with a given mortar. This does not mean, of course, that the determination of mortar density is not of great value in obtaining the relative merits of two given sands, as it might develop in an analysis of this kind that one sand would work better than another in lean mixtures and poorer in rich mixtures. Take a fixed weight of dry coarse aggregate and one-half the same weight of dry sand. Shake them down in a cylindrical vessel and mark how high the mixture fills the vessel; then try another mixture of the same total weight, but using less sand and more coarse aggregate, or a mixture of like weight using more sand and less coarse aggregate. The relative proportions by weight which will occupy the least volume are the proportions containing the smallest possible percentage of voids. This method is very effective and requires neither apparatus nor technical skill. If conditions require proportions by volume rather than weight, as is generally the case, the experimental process will be reversed, measuring the materials placed in the cylinder and trying different compounds to ascertain which gives the greatest weight for the same total volume.

In proportioning by volume a sack of cement will be considered as one cubic foot; in proportioning by weight, a sack of cement may be accepted as 94 pounds net. In determining the amount of cement necessary to fill voids in sand, several experimental mixtures should be prepared in different proportions and the tests conducted as already described for the inert materials. This method of determining the composition of mortars is also highly recommended for determining a choice between two or more sands of like composition, because the sand which gives a mortar of least volume for like weights will always make the densest concrete.

Sizing Materials

Unless sand and gravel are purchased separately, it will be necessary to separate them by screening to arbitrary sizes before proportioning. If, for instance, it is proposed to use bank gravel varying in size from fine sand up to small boulders, two screens should be used, the first rejecting everything exceeding the maximum size of aggregate suitable for the work, this varying from ¾ inch for fence posts and block up to 2 inches for foundations and other work of large cross-section. The general rule for wall is that the largest size of aggregate shall not exceed, in its greatest diameter, one-half the thickness of the wall. The second screen should in all cases be of ¼-inch mesh, the particles retained upon it to be regarded as coarse aggregate, and those passing it as fine aggregate or sand.

Average Proportions

As many users of concrete do not wish to take the trouble to test their own materials, it is customary for them to use the proportions which have been found to produce satisfactory results under average conditions. These are one part of cement, two and one-half parts of sand, and four parts of coarse aggregate (expressed 1:2:4) for most classes of construction. In the manufacture of products large enough to use aggregate exceeding one inch in greatest dimension the proportion of coarse aggregate may be increased accordingly. Conversely, where a fine texture is desired for ornamental purposes, the proportion of cement must be increased, reaching its maximum in 1:1½ troweled surfaces. The following table gives the proportions recommended for various classes of work:

A 1:2:3 mixture for:
- One-course concrete highway, street, and barnyard pavements.
- One-course floors and walks.
- Roofs.
- Fence-posts and for sills and lintels without mortar surface.
- Water-troughs and tanks.

A 1:2:4 mixture for:
- Reinforced concrete floors, beams, and columns.
- Large engine foundations.
- Work subject to vibration.
- Building walls above foundation.
- Silo walls.

1:2½:4 mixture for:
- Base of two-course street and highway pavements.
- Backing of concrete block and similar cement products.

A 1:3:5 mixture for:
- Supporting walls and foundations.
- Small engine foundations.
- Base of sidewalks and two-course floors.
- Mass concrete footings, etc.

MORTAR

1:1½ mixture for:
- Wearing course of two-course floors.

1:2 mixture for:
- Scratch coat of exterior plaster.
- Facing blocks and similar cement products.
- Wearing course of two-course walks, street, and highway pavements.

1:2½ mixture for:
- Finish coat of exterior plaster.
- Fence-posts when coarse aggregate is not used.

1:3 mixture for:
Concrete blocks when coarse aggregate is not used.
Cement drain tile when coarse aggregate is not used.

Amount of Water

The consistence will depend upon the use for which the concrete is intended and upon the process of manufacture necessarily associated therewith.

Three consistencies or mixtures, determined by the amount of water used, are generally called the dry, the quaky, and the wet. The dry mixture is of the consistence of damp earth, and is used where the concrete is tamped into place, being principally useful in steel molds for making products requiring no reinforcement, such as brick, block, and ornamental cases.

The quaky mixture is so named because it is wet enough to quake or shake when tamped. It is used in all molded products requiring reinforcement, such as fence-posts, lamp-posts, telegraph and telephone poles, drain tile, sewer-pipe, ash-pit rings, and the like; also in engine foundations and the footings of buildings.

The wet mixture contains sufficient water to permit of its flowing from a shovel or wheelbarrow, but not enough to cause a separation of the particles. It is used in building reinforced concrete structures, such as silos, barns, dwellings, and other buildings where the concrete is allowed to remain undisturbed in the forms for several weeks. The scum (or laitance) should be scraped from the surface of green concrete and the surface thoroughly scrubbed and moistened before placing additional concrete.

There is a pronounced tendency at the present time to use too much water. This results in concrete which is porous and of very low initial strength. There are very few instances in actual construction work where a plastic wet mix will not be satisfactory and a word of warning should be sounded against the use of very wet, sloppy mixtures.

II. Mixing

Fundamental Principle

The importance of thoroughly and carefully mixing the ingredients used in the manufacture of concrete is secondary only to the proportioning, because the mixing cannot be done until after the proportioning has been accomplished. It is secondary in time, but equal in importance.

As stated earlier in this lesson, an essential feature of concrete construction is the coating of every grain of sand with a film of neat cement, and the coating of every piece of coarse aggregate with sand-cement mortar. This statement may be emphasized by stating that it is the fundamental principle of all concrete construction; an earnest effort to accomplish this result will insure success.

In machine mixing experiments show that for periods up to two minutes the strength of concrete made from the same materials and with the same percentage of water is proportional to the time it is kept in the revolving mixer.

Assuming that proper proportions have been determined, the result so carefully sought can be attained only by thorough and intelligent mixing.

Shovel Mixing

Let us first consider the rather difficult problem of securing satisfactory results where the volume of work does not warrant the installation of a mixing machine.

The first requirement will be a water-tight platform large enough for two men to shovel conveniently from either end as large a batch of concrete as can be used within thirty minutes after water has been added to it.

If, on account of meal-time or any emergency, a portion of a batch lies until the cement has become partially hardened, throw it away rather than jeopardize the work.

As proportioning is usually done by volume, one cubic foot is a convenient unit, as it allows full sacks of cement to be used. The required amount of sand should first be spread upon the mixing platform, after which the cement should be spread in a layer on the sand. Two men, using square pointed shovels, will then turn the sand and cement over two or more times until the streaks of brown and gray have merged into a uniform color throughout the mass. The coarse aggregate is then added and the mixing continued, water being added during the first turning after adding coarse aggregate. Water should be added gently, as from a hose nozle or the spout of a watering-pot, in order to prevent washing out the cement. Turning should continue until the mortar is of uniform consistence throughout, which will usually require at least three turnings after adding water.

Mixing in the above manner will give satisfactory results, but the labor involved is considerable, and on this account it is too common for those attempting it to slight the work and use the concrete in an imperfectly mixed condition.

Machine Mixing

Mixers have been brought to a high state of efficiency, and to-day there are many on the market designed to produce the best results at minimum cost of labor and power. While it is beyond the scope of this lesson to discuss mixers, we may, in passing, mention one or two of the principles which will assist the concrete manufacturer in making a selection suited to his needs. The batch-mixers, whether cubes, cylinders, or truncated cones, allow the material to be introduced in any order desired, provided only that each separate batch contains the proper relative proportions of ingredients. After the batch has been placed in the mixer, it is revolved for a specified time, or a definite number of revolutions, until either by the shape of the drum itself or by means of deflectors therein the cement, sand, and coarse aggregate have been thoroughly mixed. Most batch-mixers are equipped with a small tank from which a pipe leads into the mixer, and when the materials have been sufficiently mixed in a dry state, water is sprayed on them while the revolutions of the mixer continue.

The continuous mixer consists mainly of a number of hoppers for the several materials, placed over one end of a semi-circular trough containing blades or shovels fixed to a rotating shaft. The motive power is generally supplied by a gasolene engine or an electric motor. The dry materials are fed automatically from the hoppers into the trough, mixed, and carried along by the blades to the discharge end, water being added; meanwhile the concrete is discharged continuously.

The batch type of mixer is considered by the majority of engineers to give the best results because the measuring of the materials can be positively regulated, whereas with the continuous mixer variations in the amount of moisture in the sand or fluffiness of the cement will cause a variation in the relative proportions of these materials in the mixture. On this account engineers favor the batch-mixer.

Lists of manufacturers of mixers will be found in the columns of current concrete periodicals.

III. Placing

Final Problem

But when all is said and done: when we have selected the best materials, have ascertained the proper proportions of each and the correct amount of water for the consistence required to serve our particular purpose; when by shovel or machine we have combined the different materials required to make concrete, we have produced a mass of material which must be carefully deposited, compacted, and made to take some one of the thousand and one shapes which concrete assumes.

This, then, is our problem, the placing of the concrete, and we shall find three distinct methods of accomplishing this result:

Pressure and Tamping

Whenever a dry mixture is used in steel molds to produce such unreinforced products as ornamental vases, block or brick, concrete is placed by pressing or tamping. If pressure is applied, it will ordinarily be by means of a press simplifying the process and making it necessary only to see that the molds are adequately and evenly filled in order that the product may be uniform in density. If, however, tamping is the method employed, considerable supervision will be found necessary, as the quality of the product may vary considerably unless the tamping is uniformly performed. It is particularly necessary that the mold be tamped while filling, not filled and tamped afterward. The latter method will not only fail to fill the lower corners, but will make one-half of the molded product much denser than the other. If tamping is well done by one man (or two, if a large mold) while the mold is being filled by another, there is no reason why the product should not be perfectly satisfactory and as uniform as though made under mechanical or hydraulic pressure. To secure more uniform density and effect a saving of labor, power tampers are used, the multiple tampers being especially serviceable in making block and brick.

Agitation

Neither tamping nor pressure will be of service in the case of those products requiring the introduction of reinforcement, such as tile, pipe, poles, and posts. In the manufacture of these and similar products the steel, in whatever form required for reinforcing, is introduced at the proper place in the mold while it is being filled, with a quaky mixture of concrete which is compacted, forced into corners and around or through the reinforcement, by vigorously stirring the mixture and jarring the mold.

Depositing Wet Concrete

Placing concrete for reinforced concrete structures, including silos and all sorts of buildings, involves work on a scale warranting the installation of special apparatus to save both time and labor in transporting the concrete from the mixer to the place of use. Elevators, dump-cars, and chutes are ordinarily used in the construction of reinforced concrete buildings. In constructing silos it is economical to provide a center hoisting device with derrick and an automatic dumping bucket.

The concrete is poured into forms in which reinforcement has previously been placed. It is then necessary to spade it back from the forms in order to prevent large pieces of aggregate from retaining surface positions when the forms are removed. The larger pieces of aggregate should, as far as possible, be forced away both from the reinforcement and the forms, so that they may occupy an intermediate position. Though the subject of forms is treated in another lesson, a word of caution relative to their removal may not be amiss at this time. While no definite rule can be given to fit all local conditions and variations of structure, humidity, and temperature, good judgment will suggest that too early removal involves danger, while reasonable delay in removing forms is a wise precaution, insuring safety.

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IV. Forms

Introductory

The plasticity of concrete, and the readiness with which the material can be adapted to all shapes and sizes of construction, have from the beginning of the more extensive use of concrete made the production of molds of desired form a very important consideration in all concrete construction work. While iron and steel molds have been used for small members, such as block and brick and ornamental pieces, in which the same design and size can be indefinitely repeated, larger concrete construction requires individual design, determined by local conditions and particular needs. The ease with which concrete may be adapted to such peculiar requirements of individual use is one of the chief merits of the material. Consequently, means must be provided for constructing, at or near the place where the concrete is to be used and from materials easily procured, molds which may be made to fit the circumstances of each individual case. Molds of this diversified character are commonly called forms.

Classification

Forms may be roughly classified as follows:

1. Rectangular forms wholly of lumber.
2. Rectangular forms using metal fastening devices.
3. Rectangular metal forms.
4. Circular forms of wood and sheet metal.
5. Circular forms wholly metal.
6. Miscellaneous.

Lumber Forms

Contrary to the usual practice in building construction, green lumber will keep its shape in all rectangular forms better than lumber that is thoroughly dry. If dry lumber is used, it should be thoroughly wet before the concrete is placed. The use of oil or grease free from animal oils or fats on the inside of forms is recommended, as it prevents absorption of water from the concrete by the forms and makes their removal easier. Where any fine ornamentation is used, the molding or other device introduced to vary the surface should be painted with equal parts of boiled linseed oil and kerosene. it is, however, essential that forms should be thoroughly cleaned each time they are used, and that no dry concrete be left sticking to the face of the forms. Forms may be built from stock length lumber, requiring very little sawing and permitting of the lumber being used later for other purposes. White pine is considered the best lumber for forms, although spruce, fir, and Norway pine are often used. The face of forms should be free from loose knots, slivers, or other irregularities, as concrete will reproduce them all with great faithfulness. Matched lumber may be used to afford a smooth finish, and very satisfactory results can be obtained by proper care in the construction of forms.

Rectangular Forms

In the construction of rectangular forms the first type of construction presenting itself for consideration is foundation work. Where the excavation is made simply for a foundation without cellar or basement, the soil will often be firm enough so that the trench, if carefully excavated, may be used as a form below ground line. In this case the edges must be protected to keep the dirt out of the concrete. In carrying the foundation from the ground line to the level of the first floor, forms must be constructed resting upon a bridge and extending slightly below the ground line. These forms may be constructed in sections or built in place.

If the inner and outer parts of the form are built separately, they must, when put into position, be leveled and plumbed carefully. Whether built in sections or built in place, forms must be braced thoroughly and tied together, as the essential duty of any form is rigidly to maintain its integrity until the concrete has hardened.

Forms for foundation piers and for the foundation of all kinds of machinery are constructed in substantially the same manner as for regular building foundations. The construction of machinery foundations is essentially a problem of securing the necessary mass and weight, consequently the greater part of the foundation will be under ground, and all that is required above ground is an open box of sufficient strength to maintain the concrete in the desired form while hardening.

Where the excavation for cellar is made by team and scraper, the sides will not be perpendicular, and the excavation will usually be somewhat larger than the dimensions of the cellar-wall. Consequently it is necessary to use both inner and outer forms. Each form is braced by uprights spaced close enough to prevent any spreading or bulging of the sheeting when subjected to the outward pressure of the fresh concrete. The inner form should be securely braced in a perpendicular position by lumber braces from the floor of the excavation. The outer form should be fastened to the inner form by wires running through both near the bottom, and at the same place the forms should be separated by spacing blocks of the width determined upon for the cellar wall. The outer form should, like the inner, be perpendicular unless a slight batter is desired, in which case the spacing blocks should be lengthened to spread the bottom of the forms apart and increase the thickness of the wall at the bottom without interfering with the established thickness of the wall at the top. The wires connecting the two forms should be drawn tight by twisting with a large nail or rod until the forms are drawn firmly against the spacing blocks. The top of the uprights should be joined by cleats. The method just described produces a very rigid form.

When an outside cellar or basement entrance is desired, the forms for same should be constructed simultaneously with the cellar wall forms. When in position, these forms will rest upon the floor of the excavation made for the steps. If the excavation for the entrance is carefully made, only the inside form will be required until ground line is reached. As the walls will project above the ground where they join the building and slope from that point to the opposite end of the entrance, an outside form will be required above the ground line. By properly bracing the form, one side wall may be made, and after it has hardened the form reversed and used for the other side. After both side walls have been made, forms for the steps giving desired height of riser and width of tread may then be securely braced between the side walls.

In the construction of double walls, such as in ice-houses, the intervening air-space is not usually wide enough to accommodate two sets of forms. Therefore the hollow wall is usually constructed by placing in the forms cores which are later withdrawn.

Forms for walks and floors should consist of 2-inch lumber, in width equal to the desired thickness of the walk or floor, staked in the earth to form slabs of the desired size. The concrete is mixed wetter than for two-course work, and where the walk or floor is laid in one course, slabs should be laid alternately, allowing cross forms to remain in place until ready to fill intermediate slabs. This method is also used extensively in two-course work, although many prefer to work consecutively, moving the cross-piece each time a slab is completed. If laid continuously, care must be exercised to preserve the vertical joints through the entire walk. Horse blocks or carriage steps may be constructed where the walk joins the driveway by the use of simple box forms.

The modern farmer is making use of concrete for the construction of various types of tanks, such as the stock watering tank, the hog feeding trough, the dipping vat, and the hog wallow, all of which may be constructed by the use of rectangular lumber forms.

The general method of constructing rectangular tanks above ground consists in erecting an outer form, usually of 2-inch lumber, in which the concrete floor of the tank is placed, and the surface finished as desired, after which the bottomless inner form, which must be previously prepared and ready for immediate use before the previously placed concrete has hardened, is quickly inserted and securely fastened in place by cleats joining the uprights of the outer and inner forms. The method of constructing rectangular tanks underground differs only in that the earth usually forms the outer form and a wood form is required for the roof. In constructing septic tanks provision must be made for the several partitions and compartments necessary to secure decomposition of the sewage and disposal of the effluent.

Two methods are used with equal satisfaction in manufacturing small troughs, which need not necessarily be built in place. One is to use a box mold and finish the interior with a straight batter or a concave surface by striking it out with a templet. The other method is to use a core of firm clay or wood made in shape to correspond with the inside of the trough. A bottomless box is placed over the inverted core, and by filling the box with concrete and striking it off level, the trough is manufactured upside down.

The simplest deviation from home-made molds is to purchase clamps for holding forms in place, thus doing away with nailing them to the uprights. There are several systems of clamps on the market, some of which are very ingenious, and all of which are designed with two purposes in view, the first being to facilitate the erection and removal of forms, and the second being to save loss of lumber from repeated nailing and tearing down.

A still wider departure from the home-made forms brings us to those constructed wholly of metal, which provide a rapid and economical method of concrete construction where a large amount of work is to be done along uniform lines. Only continued repetition, however, will justify the purchase of metal forms. Where the opportunity occurs to rent metal forms for any work of considerable importance, a saving may be effected and the quality of the work somewhat improved on account of greater surface uniformity secured by use of the metal forms.

Circular Forms

Circular forms are extensively used in the construction of tanks because a round tank is more economical to build and will resist frost action better than a tank of any other shape. The construction of a circular form presents greater difficulty than does that of a rectangular form, and it is usually better for several of those who desire to construct tanks to determine upon a standard size and join in the use of a set of forms, or, if this cannot be done, a set of forms may be rented if but a single tank is to be made. For a 10-foot circular tank, 2 feet 6 inches in depth, the forms usually cost about $50, while the cost of the tank itself, exclusive of sand and gravel, is only $30. Forms for circular tanks consist of an inner and an outer wooden frame covered with sheet iron. Silo forms may be used for the outer forms of large tanks. The height of the inner form is equal to the inside depth of the tank, and the height of the outer form is equal to the sum of the inside depth and the floor thickness of the tank. After the inner and outer circles of the form have been laid out, segments are cut from 1-inch lumber and a wooden frame is built up, fence fashion. No. 22 gage galvanized iron is then attached by screws or nails. The inner form should slope toward the outer one, to give proper batter to the inside of the tank, and prevent bursting in case of freezing.

The selection of silo forms presents to the modern farmer one of the most important problems in connection with the use of concrete. What are known as home-made silo forms are usually constructed in 3-foot sections, but it is hardly desirable to construct a set of forms for the express purpose of building one silo. It is far better for farmers to unite in the matter, as a set of forms may be used for constructing a large number of silos. However, if one must build his own forms, a most ingenious model is that of Mr. David Imrie, Roberts, Wisconsin, who has introduced his form to hundreds of farmers in connection with the work of the Wisconsin Farmers' Institute. The inner form consists essentially of hooped sheet metal securely clamped and braced. No. 28 gage galvanized sheet iron is used, and the form is assembled in eight segments which are bolted together. The outer form is made of 18 or 20 gage galvanized sheet metal 3 feet in width, in two or more pieces, joined by heavy band iron riveted to the ends of each piece, which is turned at right angles and drilled to receive the bolts drawing adjoining sections together. Forms of this type have been built at a cost varying from $25 to $50.

Practically all silos now built are roofed. The construction of the roof form is a simple matter, requiring only a box for the cornice and 2 inch by 6 inch rafters radiating from the apex to the roof edge, on which 1 inch by 6 inch sheeting is laid to receive the concrete.

Many commercial systems of silo construction are now upon the market. Fortunately, most of them are meritorious and will result in more satisfactory work than can be obtained from home-made molds inasmuch as they effect many economies in the methods of handling materials and assembling the forms. The various commercial silo systems are operated under different methods. The forms are constructed wholly of metal, and some companies sell them outright to an association of farmers who desire to construct silos; some companies rent their forms for the construction of a single silo; some companies construct a silo for the farmer, acting in the capacity of contractors and guaranteeing their work in every way.

Miscellaneous Forms

The miscellaneous uses of concrete about the barn, barnyard, and farm in general are innumerable. The preparation of forms for the many uses to which concrete may be put affords pleasant exercise for the ingenuity of any one familiar with the uses of concrete. A few of the possibilities of smaller construction are merely suggested: concrete stalls, mangers, hens' nests, hotbeds, pits for wagon scales, curbing for old wells, pump pits, and waste-water receptacles. The form for the last mentioned consists of earth excavation for the outer form and an empty half barrel for the inner form, which indicates how simple concrete construction may be made.

The removal of the form is a matter requiring very careful consideration. A great deal of work has been injured and not a little has failed because of undue haste in removing forms. Two or three days' additional time allowed to new concrete before removing the forms often marks the difference between defective and thoroughly satisfactory work.

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V. Concrete Foundations and Walls

I. Foundations

Advantages

Concrete is especially adapted for use in building foundations because of the following characteristic qualities:

1. Compressive strength.
2. Durability.
3. Moderate cost.
4. Ease of construction.
5. Adaptability to irregular excavations.
6. Capacity for reinforcement.
7. Can be placed under water.

Plain, or unreinforced, concrete shows its greatest strength under direct compression. Carrying capacity is the quality chiefly sought in the selection of material for the foundation of any building. Moreover, concrete lasts forever without repairs, and permanence is a consideration scarcely secondary to strength in determining a choice of foundation material. The cost of a well-built concrete foundation is considerably less than that of one constructed of any other building material of equal strength and durability. Under average conditions the time required for building a concrete foundation is shorter than that required for one of brick or stone. Concrete is the only foundation material which readily adapts itself to slopes, change of grade, or other irregularities in the subgrade on which the foundation is laid. Wherever conditions require a foundation of restricted area on a side hill, exposing a portion of the foundation wall to danger of accidental injury, or vibration of engines and other machinery must be withstood—in any of these cases concrete demonstrates its adaptabiilty by permitting the introduction of sufficient reinforcement satisfactorily to perform the duty demanded.

Owing to the fact that Portland cement has the property of hardening under water it is now almost universally used for construction work carried on below water. Care should always be exercised not to deposit it in running water, inasmuch as the water will carry away a portion of the cement and thus decrease the strength of the concrete.

Consequently, concrete is supplanting all other materials for building foundations of every character, irrespective of the character of the superstructure. Some of the principles which must be observed to secure the best results will be here outlined:

Materials

The proportioning, mixing, and placing of concrete has been thoroughly discussed in another lesson, and the practices therein recommended should be rigidly observed. Further, it is often possible in foundation work to increase the size of the largest aggregate up to 2 inches or even 2½ inches. Wherever large sizes of clean, hard, durable gravel or broken stone can be used, additional strength is secured; for this purpose field stones may be employed advantageously.

Excavation

In preparing for the erection of any rectangular structure a base line should first be determined upon, and from the base line the several corners should be ascertained by accurate measurement at right angles or at such other angles as may be desired in structures of irregular shape. The corners should be staked and definitely fixed by a tack driven in the top of each stake. All measurements and angles should then be checked back to the base line. Several feet outside of the line of stakes other stakes should be set to overreach the corners, or a frame may be built 10 inches above ground, called a batten board, from which lines are then run to pass exactly over the tacks set in the stakes. These lines show the outside of the proposed excavation, and by measuring the width of the foundation and running parallel lines that far inside of the first lines, the lay-out is ready for excavation.

The depth and width of excavation depend upon the height and character of the building to be erected, but should always go to solid earth, and should at least be lower than frost line. If the ground is filled with surface water at certain seasons of the year, drainage should be provided from the bottom of the foundation trench to a natural outlet.

Footings

As a convenience in setting forms, footings are sometimes provided where ground is firm. Wherever a foundation is to be constructed on filled ground, which cannot, by rolling and tamping, be made solid enough to guarantee the permanent carrying without settlement of the superimposed load, the weight must be distributed by a layer of concrete wider than the foundation itself. This is known as a footing. It may be twice as wide as the foundation, but must be thick enough to prevent shearing or cracking, and may have either sloping or stepped sides. In extreme cases of very soft earth requiring excessively wide footings cross-bars or reinforcing rods are introduced in the footings to distribute the foundation load without injury to the concrete slab.

Kidder ("Architects' and Builders' Pocket-book") gives bearing power of soils as follows:

	Bearing Power in Tons per Square Foot	
	Min.	Max.
Rock—the hardest—in thick layers in native bed	200	..
Rock equal to best ashlar masonry	25	30
Rock equal to best brick masonry	15	20
Rock equal to poor brick masonry	5	10
Clay on thick beds, always dry	4	6
Clay on thick beds, moderately dry	2	4
Clay, soft	1	2
Gravel and coarse sand, well cemented	8	10
Sand, compact and well cemented	4	6
Sand, clean, dry	2	4
Quicksand, alluvial soils, etc.	0.5	1

Concrete for footings should be mixed in the proportions of 1 sack of Portland cement, 3 cubic feet of clean, coarse sand, and 5 cubic feet of gravel or broken stone, varying in size from ¼ inch up to 2 inches; if reinforced, the proportions should be 1:2:4. Enough water should be used to form a quaky mixture, but not enough to cause the cement and aggregate to separate in placing. Concrete foundations and footings may be keyed by partially embedding in the footing vertical rods or horizontal I-beams; in light structures a similar effect may be produced by casting on the footing a central longitudinal projection which will form a tongue-and-groove joint with the foundation. If the placing of the foundation is delayed until the footing has hardened, the latter should be cleaned, roughened, and wetted, and then grouted with a mixture in the proportion of 1 sack of Portland cement to 1 cubic foot of sand, mixed to the consistence of thick cream.

Simple Foundations

Where there is to be no cellar or basement under a building and the nature of the ground is such that the excavation can be made for the exact width of the foundation, forms below ground line are unnecessary provided the earth is firm enough to prevent "caving in" of the sides. It is, however, necessary to protect the edges and sides, especially on the side opposite that from which the concrete is poured, by burlap aprons made by tacking a piece of burlap on a piece of lumber 2 by 4 inches, long enough to rest on cross-pieces bridging the excavation. When the ground line is almost reached, forms previously constructed of 1-inch boards on 2-inch by 4-inch studding must be placed to receive the concrete from ground line to the top of the foundation wall. The forms must not rest on the concrete already placed, but upon a bridge which will allow them to drop slightly below the ground line. No appreciable time should elapse between placing the concrete below and above ground, as an interval of more than thirty minutes will produce a line of cleavage, seriously weakening the wall and lessening its water-tightness.

Piers and Engine Foundations

Foundation piers for additional supports under large or heavily loaded buildings are constructed in the same manner as simple foundations, the size being determined by the estimated load and the character of the ground. The footing is important, as the sole object of such construction is distribution of the load.

Foundations for gasolene or steam engines and for any machinery subject to considerable vibration are constructed in the same manner as foundation piers. The size and depth are determined by the amount of vibration to be withstood. The problem is simply to build in the earth a solid block of concrete of weight sufficient to withstand the action of the engine bolted to its top. Casings for the bolts are made of 2-inch pipe, resting on plates at the lower end of the bolts; they are embedded in the concrete and provide for any necessary adjustment of the bolts when setting the engine in place. The length of each casing equals the length of the bolt to be embedded; by tightening the nut on each bolt above the templet the casing fits snugly against the templet, and the top of the bolt is brought to proper height. The templet can be made from 1-inch material, and will be sufficient for placing the casings in smaller engine foundations; for larger foundations cross-bracing should be added. In setting bolts first nail the templet securely in place, then mark accurately the position of the bolts, and bore holes only slightly larger than the bolts. Be sure the bolt holes are correctly located. Bolts and casings are now set in place, centering casings with bolts by several nails or by wooden strips lightly nailed on the under side of the templets. Proportions of 1:3:5 may be used in foundations for gasolene engines and cream separators. A mixture of 1:2:4, using aggregate up to 2 inches or 2½ inches, is recommended for steam engines and large machinery.

II. Walls

Cellar and Basement Walls

Wherever the excavation is made for a cellar under a building, the problem includes not only the construction of a wall to serve the purpose of a foundation for the superstructure, but of one which will also insure a cellar warm in winter, cool in summer, and dry at all seasons. Concrete walls of suitable thickness solve the problem of heat transmission, and if properly built, the cellar will be always dry. Proper drainage should, however, be provided. While a concrete cellar wall may be constructed so impermeable that water standing outside will not penetrate to the interior, drainage to natural outlets is a wise precaution and should not be omitted except in soil that is dry all the year around.

When the cellar excavation (often made by team and scraper) has irregular sides and is somewhat larger than the actual dimensions of the wall, it will be necessary to use both outside and inside wall forms. Only in small excavations shoveled by hand and left with true sides in firm earth free from indications of caving can the earth be used for the outer form.

In using forms for both the outside and the inside of the wall quite a large amount of lumber would be required if forms for the entire work were constructed at one time. To obviate this, forms can be built in sections, each section being of the full height of the cellar wall, and as long as convenient to build and set in place. An entire section should be filled at one operation in order to avoid horizontal joints or lines of cleavage in the concrete.

At the end of the section a piece of 2-inch by 4-inch lumber, with both edges beveled to permit of easy removal, is fastened to the face of the partition board used as a stop-off at the section's end. This makes a tongue-and-groove vertical joint. When the forms are ready to fill for the adjoining section, the end of the partially hardened section must be cleaned, wetted, and coated with neat cement grout mixed to the consistence of thick cream. Attention is called to the preference in building practice for vertical joints in foundation and cellar walls, whereas horizontal joints are preferable in the upper part of the building.

Sectional forms are better and more economically constructed by building them flat upon the ground than by constructing them in the position in which they are to be used. Care should be exercised to build them true and to have the face as free from irregularities as possible. The sheeting for the inside of the wall should be surfaced on the side next to the concrete, to give a smooth interior finish.

The outer and inner form should be joined at the top by nailing cleats between the uprights, being careful to separate the forms the exact width of the wall. The forms should be united a short distance from the bottom by double wires, and should be separated at the same place by wood spacing blocks of a length equal to the thickness of the wall. When the spacing blocks are placed, the double wires are twisted by the use of a large nail, so that the outer and inner forms are firmly fastened together. They are supported by securely bracing the inner form so that the wall will be plumb.

If desired to provide the foundation with greater resistance to lateral pressure, or to afford a firmer base, "batter" in the wall may be secured by lengthening the spacing block which separates the outer and inner forms.

Anchor bolts are embedded in the top of the concrete at suitable intervals for fastening the wall plate to the foundation.

Cellar Floors

The methods of building concrete walks are fully described in another lesson. The methods of building cellar floors are similar. To avoid repetition, only the points of dissimilarity will be stated here.

Where the ground is firm and well drained, the subbase may be omitted and the concrete floor laid directly on the ground.

Drainage should be provided, preferably toward the center of the floor. The top of the floor should be given grade enough that water accumulating from scrubbing or other causes will run off through a tile drain laid beneath the floor and communicating with a natural outlet.

Where a basement floor is below the level of ground water, the floor should be laid in a single sheet instead of being divided into slabs. The concrete should be mixed in the proportions of 1:2:3, and the floor reinforced in both directions with ¼-inch rods 8 inches apart, or by wire mesh having an equal cross-sectional area of metal.

Entrances

Outside entrances to cellars should be constructed by building, at right angles to the cellar wall, forms for side walls sloping from the top of the foundation down to the ground and from the cellar floor up to the top of the proposed stairway. If excavation is carefully done, the earth may usually be used for the outer form. By pouring one side wall at a time, and reversing the form by changing uprights to the other side of the sheeting, one form may be used for both sides of the entrance. The form for the steps may be built after the side walls are hard enough to remove the forms. After the desired measurements of tread and riser have been decided upon, the plan should be laid out on the side walls, cross-pieces wedged between them and secured by bracing. The concrete used in the construction of the base should be as wet as possible without flowing from one step to another.

The ¾-inch facing course of the risers may be placed either by using a thin metal partition or by plastering the mortar on the inside of the face form before placing the coarse, wet concrete. The wearing course of treads is placed as in sidewalk work, and should be finished by wooden float to a surface reasonably smooth but rough enough to afford a good foothold.

Window-frames

Closer joints will be secured under cellar windows if the frames are not placed until the concrete has hardened. Extreme care should be taken to have the opening true, thus simplifying the work of placing the frames and making the joints tight.

Finish

Concrete for cellar walls should be of such consistence that when poured into the forms it will settle to place by gravity. While the forms are being filled the coarser aggregate should be spaded away from the face of the wall, bringing the mortar next to the forms. The mixture recommended for foundations and basement walls, 1:3:5, provides an excess of mortar for this purpose. Spading is equally important on the interior and the exterior. On the interior it gives a more finished surface, and on the exterior it increases water-tightness. On the outside of the wall, above ground line, the plastic appearance which walls will have after forms are removed may be overcome by removing the surface film of mortar by brushing with a wire or a stiff fiber brush and washing the wall with the acid solution mentioned in the lesson "The Surface-Finish of Concrete."

Removal of Forms

Not only the proportions of ingredients and consistence of concrete itself, but the weather conditions have marked influence upon the time of hardening. Consequently no definite rule can be given for removal of forms. Two to three weeks will suffice under average conditions. Where the earth is utilized for the outer form more time will be required than where both forms are of lumber. Too early removal spells failure, and judgment must be exercised.

Block Foundation Walls

Well-made concrete blocks are extensively used for foundation and cellar walls. For the latter purpose they possess the advantage of an interior air-space which helps to preserve an even temperature in the cellar. Care should be exercised that the blocks are well made of properly selected and proportioned materials, mixed wet enough so that the percentage of porosity and absorption will be low. For both foundation and cellar walls blocks must invariably be laid in cement mortar mixed in the proportion of 1 sack of Portland cement to 2 cubic feet of sand, and the joints must be thoroughly filled. For the even and correct filling of joints, a templet or mortar gage may be obtained from the manufacturers of leading block machines.

Walls for Superstructures

The recent statement that the annual fire loss of American farm buildings equals one-fourth of their total cost should be sufficient argument for concrete—a material that will not burn.

There are several methods of using concrete for the main portion of all classes of buildings. The most common forms of its application are concrete block and monolithic walls. The concrete block is fully discussed in another lesson. Monolithic walls may be either plain or reinforced. The principal reason for reinforcing monolithic *concrete* walls is to prevent cracks from the expansion and contraction of the concrete caused by changes in temperature. All walls exceeding 12 feet in height should be protected by sufficient horizontal and vertical reinforcement, which should depend upon dimensions and design of the particular structure. It is seldom necessary to reinforce monolithic walls over 8 inches in thickness when less than 12 feet in height, except around window and door openings. One-quarter-inch rods should be placed from 1 inch to 2 inches back from the surface of the wall, and 2 inches from the angles of openings; three rods above and two on each side of the openings; two rods below windows; all projecting 10 inches beyond point of intersection. Diagonal rods 2½ feet long should be placed to pass intersections of horizontal and vertical rods.

The monolithic concrete wall lends itself more readily than any other type of building construction to the individual taste of the builder as to variety of design. In this respect it has no limitation except that of the builder's ingenuity in the construction of forms. Forms for walls above ground must necessarily be more carefully constructed than those for cellar work, as more perfect alinement is required and better surface finish desired. Home-made forms are, however, often used, being built from 2-inch plank surfaced on one side, braced within and without and tied together in the manner already described for cellar walls. In building walls above ground level continuous forms are sometimes used to avoid vertical joints.

Several systems of clamps are now manufactured for constructing forms of 2-inch plank. They generally provide for courses 24 inches in height, the same form being moved upward as soon as the last course has hardened sufficiently, thus effecting a great saving in lumber, although requiring a little more time in building.

Metal forms are now obtainable and are in use by numerous contractors. They are serviceable and satisfactory and may be rented by the individual user from many of the manufacturers.

REFERENCES

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"Concrete Plain and Reinforced," by Taylor and Thompson. Published by John Wiley and Sons, New York City.

VI. The Surface Finish of Concrete

Concrete is a product resulting from scientifically combining certain ingredients to form a material useful in construction because of its own distinctive merits and not because of its resemblance to any other natural or artificial product. When properly treated, it develops beauty; it is not the beauty of onyx, marble, or granite, but the beauty of concrete. If taken for what it is, rather than what it resembles, its qualities, uses, and advantages are found worthy of exhaustive research.

Mortar Facing

Whenever it is desired to secure a rich mortar surface, one of three methods is employed. A mortar mixed to the consistence of paste may be spread on the inside of the forms and the concrete filled in behind it and all tamped at one operation, to secure a good bond. A board or block of the desired thickness may be inserted, the concrete filled in, and the board removed, leaving a space to be filled by the mortar, using in this case a slightly wetter mixture. The third method, and by far the most general practice, consists in using a partition of sheet iron or steel having angle iron attached to one side to gage the thickness of facing mortar. Handles are attached to the top so that, as the face mortar is placed in front first and the concrete behind, the partition is gradually moved upward. The use of a rich mortar is not so prevalent as it was in the earlier stage of the concrete industry, because, as will be explained, far more pleasing effects may now be secured by other methods.

Spading

Where a smooth concrete surface is desired, a spade or face cutter is used, which is forced down beside the forms while the concrete is being placed, forcing the coarse aggregate back and allowing the mortar to fill the spaces next to the forms, resulting in a surface as smooth as the face of the forms.

Sand Rubbed Surfaces

Probably the cheapest method of finishing a smooth concrete surface consists in removing the forms at the end of a period varying from six hours to three days, according to the weather conditions, and finishing the surface by the use of a plasterer's float or small board, using sand and plenty of water between the board and the wall to do the cutting. If this work is done at a time when the concrete is neither too green nor too hard, good results can be cheaply secured, as a laborer will in this manner cover 100 square feet in an hour. This method of finishing is recommended for factory construction and the rear of apartment buildings, and in general for such walls as do not require special treatment.

Experimentation

Careful trials should be made before undertaking any artistic treatment upon actual construction work. The possibilities and variations in this work are unlimited, and some methods of work are expensive. Consequently any one intending to attempt the construction of an artistic surface should first try out the proposed method on several small samples from 6 to 12 inches square.

The surface desired will determine the selection, gradation, and proportioning of the aggregate, and will also influence the consistence of the mixture. Some of the more common materials selected for aggregate will be limestone, granite, marble chips, and other stone and gravels and sands of various colors.

Whenever it is necessary to use expensive materials to obtain the surface finish desired, they are used only in the mixture applied as a facing for surfaces to be exposed. As a rule, the facing mixture varies from 1 to 1½ inches in thickness, the remainder of the work being of ordinary concrete. However, both must be placed in the forms at the same time to insure a perfect bond and a solid mass. The third method, already described, for placing mortar on the face of concrete work is recommended in this connection; that is, the use of a partition of sheet iron or steel. As rich mortars always have a tendency to develop minute cracks, they should be avoided, so far as possible, and a mixture of 1 sack of Portland cement to 2½ cubic feet of aggregate is therefore recommended in the production of artistic concrete surfaces. The thickness of the facing material should not be less than one inch when fine aggregate is used, and whenever coarse aggregate is used it should be at least twice as thick as the greatest diameter of the largest aggregate used.

Brushed Surfaces

It is sometimes desirable to remove the plaster-like appearance of the concrete as it comes from the forms. One of the best methods of overcoming this is to remove the forms in about twelve hours (it being always understood that the time of removal is dependent upon the weather and the nature of the construction). As soon as the forms have been removed, if a brushed surface is desired, the concrete should be brushed while still green with a steel brush or one of stiff palmetto or other fiber bristles. A good brush may also be made by clamping together enough sheets of wire cloth to make a brush about four inches wide. If the concrete hardens so that the mortar cannot be brushed away from the coarse aggregate, the mortar may be softened by a solution of muriatic acid. After brushing, the work should be treated with an acid solution, and for this purpose, if standard Portland cement has been used, the solution should be one part of commercial muriatic acid to three parts of water. After the use of an acid solution the work should be washed immediately and thoroughly with clean water, as any acid remaining upon the face of the work will ultimately cause streaks and discoloration.

The following materials are recommended as suitable aggregates for the production of desirable brushed surfaces, it being understood in using any of them for aggregates that the mixture is to be 1 sack of Portland cement to 2½ cubic feet of aggregate:

Yellow marble screenings up to ¼ inch; red granite screenings up to ¼ inch; black marble graded from ⅛ inch to ½ inch; white marble graded from ⅛ inch to ½ inch; river or lake gravel graded from ¼ inch to ½ inch.

To secure economy, limestone may be substituted for white marble, and either black granite or trap-rock may be substituted for black marble.

The above materials are merely suggestive of the possibilities of concrete surfaces. Infinite variations may be made by substituting and combining materials, while if one takes trap-rock, red granite, and limestone, for instance, by merely increasing or diminishing the size of one or two of the ingredients it readily will be seen that a great many combinations may be effected, all of which will produce desirable surfaces for brushing. In general, fine aggregate will produce a comparatively smooth surface of uniform color, while coarser aggregates will give greater irregularity in both surface and color, producing a somewhat rustic appearance.

One of the chief advantages of finishing surfaces by brushing is the adaptability of this process to every class of concrete construction. Park benches, lawn vases, lamp-posts, and statuary of all kinds may be finished by this process as easily as buildings.

Rubbed Surfaces

Where it is desired to leave a smooth surface in the shape produced by the forms, but to obtain a more finished surface than possible by washing with a float under which sand is used for cutting, the concrete may be finished when it is at an age of from one to two days by removing the form and rubbing the surface with a brick and sand, natural stone, emery, or carborundum.

Where it is desired to finish concrete in this manner the large pieces of aggregate should be spaded back from the forms so that the face will contain little or no coarse aggregate. If a mottled surface is desired, it may be produced by a mortar composed of one part of Portland cement and 2½ parts of white marble or limestone, either of which will rub to a very beautiful surface. While the rubbing is in process, a thin grout composed of one part of cement and one of sand should be applied and well rubbed in. The work should afterward be washed down with clean water.

Dressed Surfaces

When concrete has thoroughly hardened, it may be dressed in the same manner as natural stone, although the stone-cutter's tools require slight alterations to suit the need of the concrete. While this work is sometimes done upon concrete when it is two or three days old, the best results are obtained after it is about a month old. The great disadvantage of dressing concrete with a stone hammer at too early an age is that pieces of the aggregate will be knocked out from the cement mortar, leaving unsightly holes, while if left for a few weeks, they will become so thoroughly bonded that they will break under the hammer and give a uniform surface, much the same as natural stone.

For this purpose the best tool is a special form of bush hammer designed to dress concrete, the points on the face of which are farther apart and larger than on the regular stone-cutter's hammer. A three-pound hammer with four points is a good size for concrete work, although larger ones are frequently used. Another hammer which has been especially designed for dressing concrete is similar to a pick having five teeth on each end. This is made in two forms, one consisting of a steel head six inches long, beveled at both ends, the other being in the form of a central cast steel head to which steel plates are bolted. In the latter form the plates are removable, and when dull are replaced by sharp ones. Three-eighths inch crushed granite screenings were used for facing the exposed surface of the Connecticut Avenue Bridge, Washington, D. C., and the finish was obtained by bush hammering. Very desirable exteriors may be produced by bush-hammered panels finished with 2-inch smooth borders, as shown on the Piqua Hosiery Company's Building, Piqua, Ohio, a replica of which was exhibited at the Cement Show in 1914. By using this method all trouble in finishing corners is eliminated, and the architectural design accentuated and improved. For finishing large surfaces a pneumatic hammer is used, and produces a very uniform finish, doing the work much more rapidly than where the tools are operated by hand.

Sand Blast Surfacing

Sand blast is frequently used for finishing concrete surfaces on large construction. It removes the plaster effect left by the forms and produces a granular finish. Sand blasting involves the erection of quite a large and expensive machine, forcing sand grains from a nozle by pneumatic pressure and driving them against the surface of the wall with such violence that the sand cuts out the softer particles of the concrete against which it is thrown.

Upon a dense and thoroughly hardened surface a 3/8-inch nozle may be used, but if the surface is not thoroughly hard, say two or three months old, it is better to use a 1/4- or even 1/8-inch nozle. Crushed quartz or sharp silica sand should be used for sand blasting. If a 1/4-inch nozle be used, the sand should be screened through a No. 8 screen; if a 1/8-inch nozle is used, the sand should be screened through a No. 12 screen. Concrete should never be subjected to sand blasting until it is at least one month old. A nozle pressure of from 50 to 80 pounds should be maintained.

Colored Surfaces

For artistic work the suggestions already made with reference to the selection, gradation, and mixing of aggregate will accomplish better results than any process of artificial coloring which may be adopted. However, this paper would be incomplete if some information were not included regarding the possibilities of producing artificially colored concrete work.

The coloring-matter should never exceed 5 per cent. of the weight of the cement, and should be mixed with the dry cement before water is added. Nothing but mineral coloring-matter should be used, and the following table, taken from "Cement and Concrete," by L. C. Sabin, is generally accepted as the standard authority for amounts of different coloring-materials.

COLORED MORTARS

COLORS GIVEN TO PORTLAND CEMENT MORTARS CONTAINING TWO PARTS RIVER SAND TO ONE OF CEMENT

Dry Material Used	Weight of Coloring-matter Per Bag of Cement			
	½ Pound	1 Pound	2 Pounds	4 Pounds
Lamp black	Light slate	Light gray	Blue gray	Dark blue slate
Prussian blue	Light green slate	Light blue slate	Blue slate	Bright blue slate
Ultramarine blue	..	Light blue slate	Blue slate	Bright blue slate
Yellow ocher	Light green	..	..	Light buff
Burnt umber	Light pinkish slate	Pinkish slate	Dull lavender pink	Chocolate
Venetian red	Slate, pink tinge	Bright pinkish slate	Light dull pink	Dull pink
Chattanooga iron ore	Light pinkish slate	Dull pink	Light terra-cotta	Light brick red
Red iron ore	Pinkish slate	Dull pink	Terra-cotta	Light brick red

There will be exceptional cases where it is necessary or desirable to color concrete surfaces after the work has been completed. For this purpose cement paint should be used, several brands of which are now manufactured in a limited number of colors by reputable companies.

Designs

There remains only one feature of concrete surfaces to be discussed, and that is the production of mosaics or pattern work. The plasticity of concrete makes it lend itself particularly to the reproduction of beautiful designs of all sorts, which may be secured in a variety of ways. For the more elaborate designs the pieces of marble, if that be the material selected, should be glued face down upon tough paper in the same manner in which floor tile are prepared for laying. This paper, with the design upon it, should be placed in the form, and the concrete filled in and thoroughly rammed to place. After the forms are removed and the concrete allowed to harden, the paper should be removed by wetting; then clean the face of the finished design with the usual acid solution, 3 parts of water to 1 part of commercial muriatic acid.

VII. Cement Products

I. Concrete Blocks

Historical

The use of concrete blocks is of ancient origin, and although it is the purpose of this lesson to deal essentially with modern practice, it will be interesting to know that blocks of various forms and sizes composed of material similar to the concrete of to-day were used in many of the monumental works of the ancient world, and may still be seen in southern Europe, well preserved after the lapse of centuries.

The introduction of concrete blocks in America was, like all other uses to which concrete has been adapted, coincident with the perfection of the rotary kiln and the consequent development of American Portland cement manufacture. Houses constructed of solid blocks or of blocks separated by metal anchors and thus forming a hollow wall may still be seen after a half-century of usefulness; but these are examples built in the infancy of an industry which began to come into its own only ten years ago. At that time the idea of making blocks in shapes designed for use in constructing hollow walls, to insure warmth in winter and coolness in summer,—blocks impervious to moisture and of such weight that they could be readily made and laid,—gained so strong a hold upon the popular mind that many people rushed into the manufacture of concrete blocks without adequate knowledge of the nature of cement or of the methods necessary to insure success in any branch of the concrete industry. Fortunately, these conditions have corrected themselves, and the elimination of the ignorant and unscrupulous block-maker will follow. To-day the concrete block industry stands upon a firm foundation of experience and reliability, the comparatively new building material being one which, having proved its efficiency, has come to stay.

Utility

The fire-resisting qualities of concrete are so well known that it is necessary only to call attention to the fact that the design of the concrete block excels all other forms of concrete in this respect (excepting double monolithic walls only), because of the vertical and horizontal air-spaces within the wall, which so far prevent the transmission of heat that in numerous fires it has been observed by reputable witnesses that the exposure of one side of a well-built 12-inch concrete wall to an intense and prolonged heat did not even damage merchandise on the other side. Damage to the blocks themselves has usually amounted only to slight chipping, due to the dehydration of the outer part, or facing, often applied in making blocks.

The same feature, namely, the non-conductivity of an interior air-space, results in a decided saving of fuel during the winter and increased comfort in summer, while it especially distinguishes the concrete block as the most suitable building material for tropical and semi-tropical climates.

While it is not only possible, but commercially practicable, to make concrete blocks of water-tight texture, the interior air-space makes "assurance doubly sure" during protracted rainy spells, and effectually safeguards from the sweating so objectionable in other types of construction. Wherever the type of block used affords a continuous horizontal and vertical air-space, as in two-piece walls, furring may be eliminated.

Materials of Manufacture

The first requisite to the manufacture of a good concrete block is suitable materials. The concrete block is a composite product, and can be no better than its weakest ingredient.

The fundamental requirement is high-grade Portland cement, which must be kept in dry storage until used. Cement which has become damp enough to harden must never be used in making concrete blocks. If proportioning is done by volume, the commercial sack of Portland cement may be accepted as one cubic foot. If, however, sacks are opened before proportioning, the cement increases in bulk so materially that it is necessary to proportion by weight. (A sack contains 94 pounds net.)

Sand

The sand used in the mortar of a concrete block should be silicious, coarse and clean. If screened from bank-run gravel, care should be exercised to see that it is free from animal or vegetable matter. If foreign substances are present, they should be removed by washing the sand. The selection of aggregates and methods of determining their suitability have been given in a previous lesson.

Gravel or Broken Stone

The coarse aggregate for concrete blocks should consist of gravel or broken stone. Choice between the two depends upon local availability and desired surface finish. Crusher-run broken stone should not be used until the dust has been screened out and the stone properly sized for proportioning. Bank-run gravel must be screened and reproportioned before using. This point cannot be too strongly emphasized, as many failures are directly attributable to neglect of this requirement. Whether strength and density or economy and the saving of cement be the aim, the block-maker cannot afford to use unscreened bank-run gravel.

So far as strength is concerned, it is impossible to make a concrete block stronger than the aggregate of which it is in part composed. The ultimate strength is demonstrated when a fractured block shows the cleavage—and not the pulling apart—of the coarse aggregate.

As to surface finish, the possible variations resulting from choice of aggregate are numerous. The granites, marbles, white quartz, and gravel of variegated colors are increasingly popular for exposed surfaces. For the main portion of the block, necessarily cheaper, limestone is in most localities the best available broken-stone aggregate. Sandstones are variable in strength, and the softer ones do not make good concrete blocks. Hard, clean gravel is often cheaper than broken stone and is equally desirable.

Proportioning

When the materials have been selected, the next step will be their proper proportioning, and for this purpose it is necessary to establish an arbitrary standard of sizes—the sand grains passing through a screen of ¼-inch mesh, and gravel or broken stone passing a 1-inch ring and being retained on a sand screen.

There are certain well-established scientific methods of determining voids and establishing definite proportions, which has been fully treated in a previous lesson. For the present it may be stated that under average normal conditions a mixture of 1 part Portland cement, 2½ parts of sand, and 4 parts of gravel or broken stone (expressed as 1:2½:4) has been found most satisfactory for the body or main portion of all blocks. If it is desired to face the block with a finer material, the richness will be increased in proportion to the elimination of coarse aggregate, but 1:1½ is as rich as should be used for any face, while a 1:2 is better except in cases where decidedly fine texture, such as tooled and scrolled work, is desired.

Mixing

No matter how carefully the materials may be proportioned, good concrete blocks cannot be obtained unless the mixing is properly and thoroughly done. For important work it is both safer and cheaper to use a power-driven mixer of standard make and known efficiency. However, where the proposed work is not extensive enough to warrant the installation of a mixer, equally good results can be obtained from painstaking hand mixing, using a water-tight platform, first spreading out the sand, then the cement, mixing both together thoroughly, then adding the water and shoveling until the mortar is of uniform color; after this the coarse aggregate, which has first been thoroughly wetted, should be added, and the whole mass turned twice after its addition.

Consistence

The water used should be clean and used in such quantity that a medium wet mixture will result. By this is meant one that shows rather an excess of water, so that when a small portion of the mass is firmly pressed in the hand, several drops of water will be released from the concrete.

No other consistence of mix is now recommended, because the dry mix resulted in almost certain failure and the flowing mix was commercially impracticable for small plants, on account of the large number of molds and the consequent expense of equipment required.

Molds and Machines

Blocks are made by tamping or pressing the concrete in molds designed for the purpose, and it is manifestly beyond the scope of this lesson to discuss the various machines individually. The choice of a machine is, in the main, a matter of price, stability of construction, and minor details of operation. Most machines provide for a block of convenient size and weight, penetrated by cores which, when withdrawn, leave the hollow space which gives the concrete block its peculiar efficiency. The machines operated by pressure instead of tamping generally make the two-piece blocks; that is, the blocks do not extend entirely through the wall as do the tamped hollow blocks. Both processes—tamping and pressing—and both designs, hollow and two-piece blocks, are now accepted as good construction by engineers and architects, if the rules heretofore given relative to selection, proportioning, mixing, and consistence are observed. If they are disregarded, no machine can produce a concrete block which will be creditable to the maker or satisfactory to the user.

Curing

The curing of concrete blocks is a very important part of the manufacturing process. The setting of cement, or its crystallization, is a chemical reaction, accelerated by heat and possible only in the presence of moisture.

If cured by water, blocks should remain in a closed room for twenty-four hours, after which they may be stacked under a shed with open sides. Blocks require frequent sprinkling for two weeks, and are not ready for use until a month old. Moreover, their color is affected by the variation of moisture and heat caused by wind currents to which they are necessarily subjected in the open-air curing shed. To overcome these objections and to shorten the curing period, we strongly urge, wherever possible, the construction of a closed steam-curing room, in which the blocks may be cured for forty-eight hours in a saturated atmosphere at a temperature of 100° to 130° Fahrenheit. The time should be doubled in winter. Such curing will be more effective, as the blocks will develop greater strength in ten days than air-cured blocks will in twenty-eight days. The color will more closely approach uniformity, owing to the fact that each block thus receives the same treatment. The corners and facing of blocks will not be exposed to the usual injuries almost inseparably connected with setting green blocks in the yard. The saving of time and yard room is by no means an insignificant item. Steam curing makes it possible to operate the plant twelve months in the year.

Building Construction

The different manufacturers of concrete block machines have evolved designs for corner, jamb, and chimney blocks and other special members, according to the requirements of each particular system. These are generally well adapted to their intended usages, but the block-maker must bear in mind that corners and jambs are subjected to greater wear and greater possibility of accident than are "stretcher" blocks, and suffer more exposure in time of fire. Consequently they require special care in making and will cost proportionately more. Accessories, such as joist-hangers at floor levels and T-rods for securing roof plates, are manufactured by several reputable firms and are advertised in the columns of current concrete publications.

Footings should be of poured concrete in which the lower course of the foundation wall may be embedded. Concrete blocks 12 inches wide form an ideal cellar wall, this being ample thickness for the foundation wall of a two-story building. The walls of the first story may be of the same width, those of the second story reducing to 10 inches. Higher buildings will usually be constructed in cities or towns where thickness of walls is regulated by ordinance.

Appearance

The possible variations in surface finish of concrete blocks afford almost unlimited opportunity to the block-maker who remembers that concrete is a separate and distinct building material, possessing possibilities beyond the range of those afforded by either brick or stone. If he grasps this fact, he will cease his efforts to produce a plastic and unpleasing counterfeit of the cheaper grades of stone work. He will learn that, by proper selection of aggregate, he can secure a surface which, left plain and smooth, is as beautiful as a mosaic, or which, roughened by brushing a film of cement from the surface of a newly made block and washing the face so roughened with a 1:3 solution of commercial muriatic acid, will produce effects of startling originality and beauty.

II. Concrete Fence Posts

General Requirements

What has been said in Section I of this lesson regarding the general principles of concrete construction will apply with equal force to concrete fence posts, and will not, therefore, require repetition.

The concrete fence post, like the concrete block, is a comparatively small unit, manufactured for a particular purpose, and thoroughly seasoned before being put to its ultimate use. Consequently the same care must be exercised in the selection as well as in the proportioning and mixing of materials.

Consistence

Slightly more water is necessary in mixing concrete for fence posts than is used for blocks, owing to the different process of manufacture. A quaky mixture, which is wet enough to be just beyond the possibility of tamping, is used for posts—compactness in filling the molds being secured either by agitating the concrete by stirring or jarring the mold.

Reinforcement

In but one other respect does the concrete fence post depart from the process of manufacture applied to the concrete block. The peculiar duties demanded of the concrete fence post subject it to strains beyond the lateral resistance of a plain concrete member having such a small cross-section.

To overcome the strains and thrusts peculiar to the duty demanded of the fence post reinforcing wires or rods of steel are introduced, and it is very important, both as regards the strength of the post and the saving of material, that the reinforcement be properly placed. By imagining a post constructed of rubber and considering how such a post would act if bent far over to one side, the theory of reinforcement is easily pictured to the mind. A rubber post would manifestly be stretched on one side and pinched on the other, so we say that one side of the post will sustain tensile stress while the other will be subject to compression. As is well known, concrete is strong in compression and weak in tension, or resistance to pulling strains; hence on the side that is stretched we introduce just steel enough to balance or develop the opposing compressive strength of the concrete. Thus we secure maximum efficiency from both the concrete and the steel. We are unable to tell in advance which of the four sides of a post will be called upon to withstand the thrust; therefore, we usually embed at each corner of the post, ¾ inch from the surface, a ¼-inch steel rod, twisted bar, or wire. In this way a direct load from any side is resisted by two rods acting in unison.

Dimensions

Posts are usually made 7 feet long, 3 inches square at the top, and 5 inches square at the bottom, or they may be made 4 inches square at the top and 4 inches by 6 inches at the bottom. The dimensions first given are usually preferred, on account of the taper on all four sides making it very easy to fasten the line wire by merely tying a small wire to it and making it taut around the post. The method of making holes through posts is objectionable because of weakening the posts, and also because such holes establish an arbitrary place for fastening line wires which is frequently inconvenient and often interferes with uniformity in fence construction. The last-mentioned objection is also a fault of staple and T-shaped fastening devices of metal, which are, moreover, liable to failure from rusting on account of exposure to the weather.

Molds

The preparation of "knock-down" molds using head pieces and clamps —the lumber being protected from warping by painting with equal parts of boiled linseed oil and kerosene—is a very simple matter, and will cause no inconvenience to the ordinary manufacturer. However, if he has a large amount of fence to build, it will probably be more profitable for him to purchase a set of steel molds from one of several firms now manufacturing them in sets, known as "gang" molds, which permit making from 4 to 12 posts at one operation.

Whether a mold be made of steel or lumber, the essential points are that its sides shall be strong enough to remain true under the lateral pressure incident to filling the mold compactly, and that the mold be so constructed that the long, slender concrete post may remain undisturbed until it has attained sufficient rigidity to be removed without harm. This will usually require a week. No post should be used until it is a month old.

Hence most molds are arranged to unclamp so as to be easily removed from the post, leaving it lying on the bottom board. While there are machines for making posts in vertical position, it will generally be found more practicable to make them horizontally, placing the reinforcement in the proper places while filling the mold.

Cost

Under average conditions the cost of the materials used in a concrete post will be 23 cents. Scarcely anywhere can cedar, white oak, chestnut, or locust posts compete as to price, and when we consider the greater life of a concrete post due to immunity from fire, insects, and rot, we can easily understand its marvelous popularity.

Corner Posts, etc.

Corner posts are larger than line posts and require additional reinforcement. Eight by eight inches without taper, reinforced by four $\frac{9}{16}$-inch steel rods or other reinforcement of equal cross-section, makes a substantial corner post.

Braces may be made in home-made molds 5 inches square and 10 feet long, with proper bevel at the end and four $\frac{3}{8}$-inch steel rods for reinforcement. Lugs may be cast on the corner posts to engage the braces, or a mortise made in the face of the corner post.

On account of the small number required, gate posts will warrant additional cost and should be plain but massive, thereby materially adding to the appearance of the fence and indirectly enhancing the value of the farm.

VIII. Concrete Walks and Curbs

I. Concrete Sidewalks

Economy and Durability

When compared with any other material suitable for sidewalks, the low cost and permanence of concrete have resulted in its almost universal adoption, in enterprising communities. But it is essential that no one engage in the construction of anything so important as sidewalks are to the welfare of the community without thoroughly investigating the principles upon which success depends, and becoming entirely familiar with the best modern practice.

One- and Two-course Walks

In the early days of concrete walk construction it was the universal practice to use a base of lean concrete over which was spread a mortar top varying from $\frac{3}{4}$ inch to 1 inch, made of cement and sand or cement and stone screenings. This top or wearing surface was usually troweled to a "glassy" surface, under the belief that a very smooth surface made a stronger appeal to the public eye. Very serious objections to this practice have arisen. Not only has a surface so finished been found slippery and dangerous to pedestrians, especially in winter weather, but in cases of careless construction the imperfect bond between the top and base has resulted in the two separating, causing ultimate failure of the walk.

In the one-course construction recently introduced a single mass or thickness of well-made concrete is used, and the surface, instead of being troweled, is finished with a wooden or cork float, resulting in an even but not smooth tread, which overcomes the objection of the slippery troweled surface. Using one mixture throughout the walk, all of which is placed and tamped at one operation, does away with any possible line of cleavage or separation, consequently insuring absolute permanency, the entire slab being a homogeneous unit.

Some sidewalk contractors still feel that a saving in cost may be effected by using a leaner concrete for the base. To correct this impression, data have been collected showing the comparative cost of one- and two-course walks.

In one-course walks 4½ inches of the richer mixture is undoubtedly equal in strength to 5 inches of the two-course walk, using a leaner mixture for the base.

The following table gives the cost of materials used in the construction of 100 square feet of sidewalk, and is based upon the following prices:

Portland cement, $1.50 per barrel net; sand, $1.25 per cubic yard; gravel, $1.50 per cubic yard. (It should be understood that on account of freight on long hauls the cement will sometimes cost twice as much as shown.)

	Mixture	Bbls. Cement	Cu. Yds. Sand	Cu. Yds. Gravel	Total Cost, Materials
5-inch two-course . . .	1:2½:5 base 1:1½ top	2.52	.80	1.21	$6.79
4½-inch one-course . .	1:2:3	2.42	.73	1.08	6.16

Materials

In the construction of concrete sidewalk, as in all other concrete construction, a standard brand of Portland cement should be used.

Fine aggregate should consist of sand, crushed stone (free from dust), or gravel screenings, graded from fine to coarse and passing a screen of ¼-inch mesh. It should be clean and free from foreign matter. On account of resistance to abrasion granite screenings have been used extensively for the wearing surface where there is considerable traffic.

Coarse aggregate should consist of clean, well-graded gravel or broken stone, varying in size from $\frac{1}{4}$ inch to $1\frac{1}{4}$ inches. Bank-run gravel should never be used without screening and remixing in the proper proportions; it usually contains an excess of fine material, rendering proportions uncertain and indefinite. If the gravel contains loam, clay, or other foreign matter, it should be washed before being used.

Proportions

In the construction of one-course walk the materials should be mixed in the proportions of 1 sack of Portland cement, 2 cubic feet of fine aggregate, and 3 cubic feet of coarse aggregate.

In the construction of two-course walk the concrete for the base should be mixed in the proportions of 1 sack of Portland cement, $2\frac{1}{2}$ cubic feet of fine aggregate, and 5 cubic feet of coarse aggregate.

In two-course work the top, or wearing, surface should consist of mortar mixed in the proportions of 1 sack of Portland cement to not more than 2 cubic feet of fine aggregate.

Mixing

The importance of thoroughly mixing the materials in the construction of concrete sidewalk cannot be too strongly emphasized. Whenever possible, a power batch-mixer should be installed. On a contract of any considerable size power mixing will be cheaper than hand mixing, and every contractor has found the work of mixing by hand so laborious that the fatigue of the men has a marked effect upon the quality of the concrete.

Concrete Mixers

Batch mixers consist mainly of a rotating drum driven by steam, gasolene engine, or electric motor. Both the shape of the drum and the use of inside deflectors are relied upon to secure thorough mixing. The order in which the material is discharged from a batch mixer is independent of the order in which the materials are placed in the mixer. Hence all materials required for one batch are dumped into the mixer at one time, no attention being given to the order in which they are introduced. After the drum has made a few revolutions water in measured quantity should be added, and the mixing continued for a specified time or definite number of revolutions. A mixer must always be run slowly, to secure the best results.

Continuous mixers consist mainly of a number of hoppers for the several materials, placed over one end of a semi-circular trough containing blades or vanes fixed to a rotating shaft. Motive power is generally supplied by a gasolene engine or an electric motor. Dry materials are fed automatically from the hoppers into the trough, where water is added and the mass carried along by the blades to the discharge end.

Mixers of the batch type give better results, because the mixing is under the operator's control, and may be continued until the materials of each batch are perfectly mixed. Moreover, the measuring of materials can be regulated positively, whereas with continuous mixers variation in the amount of moisture in the sand, fluffiness of the cement, or arching of material in the hoppers will vary the relative proportions of the different materials in the mixture.

Consistence

Concrete used for one-course walk should be wetter than a mixture used for the base of two-course walk, sufficient water being used to make a quaky consistence. Enough water should be added so that when the concrete is placed and lightly tamped the mortar will flush to the surface and make finishing easy.

Mortar for the wearing surface of two-course walk should be mixed to such consistence that it will spread under a straight-edge resting on the forms, but should not be wet enough to cause excess water to stand on the surface after finishing with a wooden float. If surplus water appears on the top of the mortar, after floating, it must be taken up with a sponge or mop. The practice of throwing dry cement on a finished surface to take up surplus water should be condemned.

Subgrade

"Subgrade" is the term applied to the surface of natural soil as prepared to receive the subbase, or to receive the sidewalk directly where a subbase is unnecessary. The subgrade should not only be level, but should be practically uniform in density. If there are any holes or soft spots in the ground, they should be filled, and the filling be tamped. In the case of a fill the earth should be tamped in layers not exceeding 6 inches in thickness, which should extend at least one foot on each side of the walk, the sides having a slope of 1 to 1½. The subgrade should have a slope (toward the curb on city streets) of ½ inch to the foot, to allow for drainage, and should be 11 inches below the finished surface of the walk, except when no subbase is required, in which case the subgrade should be 5 inches (or 4½ inches) below the finished surface of the walk, depending on whether the walk is of two-course or one-course construction.

Subbase

The subbase is the foundation for the walk; it is laid on the subgrade, and is immediately underneath the concrete base. The subbase should consist of broken stone from which the fine particles have been removed by screening, coarse gravel, cinders, or blast furnace slag, the idea being to secure a porous material through which water will readily drain. The subbase should be 6 inches in thickness, laid directly on the subgrade and thoroughly tamped. On fills, the subbase should be the full width of the fill, and the sides should have the same slope as the sides of the fill, namely, 1 to 1½. Wherever the climate is such that freezing occurs during the winter, the subbase is an essential part of concrete walk construction. Only where there is no danger of frost, or where there is perfect drainage, can the subbase be safely discarded and the concrete base be laid directly upon the subgrade.

Forms

Forms may be made from 2-inch lumber, the width being determined by the height of the walk, usually 4½ inches in the case of one-course walk and 5 inches in the case of two-course walk. Thirty-six square feet should be adopted as the maximum area of a single slab, and 6 feet as the greatest dimension permissible. Places where the cross-pieces join the side forms should, in two-course construction, be very plainly marked, so that when the wearing surface is laid, the final grooving may coincide with the joint in the base. Forms must be kept well cleaned and must not be used on a new job if concrete from the last job is sticking to their face. Several well-designed steel forms are now manufactured, which may be advantageously used whenever the area of walk to be constructed will justify the initial expenditure. Construction will be more uniform if such forms are used, and in the long run they will more than pay for themselves.

Placing

In constructing one-course walk the concrete should be placed and tamped to a thickness of 4½ inches. Steel tampers are used, varying from 6 by 6 to 10 by 10 inches. For the finishing of one-course walk a steel tamper with a face 8 inches square is preferable. A commercial type has pyramidal projections, which force the coarse aggregate below the surface, leaving the finer particles at the top, ready for finishing, with a wooden float; a steel trowel should never be used for finishing any walk.

In constructing two-course walk the concrete should be placed and tamped to a depth of 4¼ inches, allowing ¾ inch for the wearing surface, which will be mixed separately, and must be placed as rapidly as possible after the placing of the base. If any considerable time elapses between placing the base and laying the wearing surface thereon, the bond between the two will be in danger.

Finishing of the wearing surface or face may be done in several ways, and while the use of a wooden float is always preferable, there are those who still wish the surface troweled. If troweling is done, it should be as lightly as possible, in order to prevent the formation of fine cracks and checks as well as a glassy surface.

The wearing surface should be cut through with a trowel directly over the joints in the base, and the groover run over the surface along the joint. Sides should be finished with an edger having a ½-inch radius.

If the laying of slabs is continuous, the cross-pieces should be removed when a slab has been completed, and the material for the next slab placed immediately. In order to insure perfect joints between slabs it is becoming quite common to construct slabs alternately. In this way the cross-pieces are allowed to remain until the cement has partially hardened before being removed and the material for adjoining slabs placed. In this manner the slabs form distinct units, and are not so likely to break in case of any future settlement in the foundation. The same result may be attained by using metal cross-pieces remaining in place until the concrete has partially hardened.

Coloring

If it is desired to vary the natural color, the use of lamp black, iron oxide, or any mineral coloring-matter is allowable, provided it is thoroughly mixed with the dry sand in quantities not exceeding 5 per cent. of the weight of the cement. Accuracy in measurement and thorough mixing are extremely necessary if uniform color is to be expected.

Protection

As soon as the concrete has hardened sufficiently to prevent the surface from being pitted it should be sprinkled with clean water and kept wet for at least four days and not be exposed to traffic until thoroughly hardened.

Freezing

Under ordinary circumstances the construction of concrete walk during freezing weather is not advocated. If circumstances make it imperative to proceed with the work at such time, the requirements on all concrete work, such as heating the water and aggregates, must be observed, and precautions must be taken to protect the work from freezing for at least five days after placing the concrete. It is essential that both the subgrade and the subbase should be free from frost when the walk is laid.

Expansion Joints

Expansion joints should be 50 feet apart and ¼ inch wide. They should be filled with tar, prepared felt, or some other material which will retain elasticity under changing atmospheric conditions.

Precautions

Walks should be grooved where crossed by driveways, and if a two-course walk, the wearing surface should be two inches in thickness at the driveway crossing.

Where a new walk joins an old one and either the grade has been changed or the old walk was not properly laid to grade, laying an entire slab at the grade necessary to joint the two walks will avoid the unpleasant and dangerous beveling that is sometimes seen.

In laying a walk around trees 6 inches clearance should be allowed to provide for future growth. The character of the trees should be investigated, as trees having lateral roots on or near the surface of the earth are almost certain to cause trouble at some time.

II. Concrete Curb and Gutter Combined

Combined curb and gutter is recommended only for streets which are not to be improved by permanent pavement. Where a street is merely graded or surfaced with disintegrated granite or some similar material, it is necessary to construct concrete gutter in connection with the curb.

Similarity to Sidewalk Construction

Concrete curb and gutter is closely associated with concrete sidewalk construction, not only on account of its position when placed, but because the materials and method of using them are much the same.

What has already been said in this lesson in regard to cement selection of fine aggregate and selection of coarse aggregate for concrete sidewalk applies equally to concrete curb and gutter.

Materials must be mixed with the utmost thoroughness, and a batch-mixer should be used whenever possible. If the mixing must be done by hand, it should be upon a water-tight platform, according to the best methods, which involve spreading the sand, then the cement, mixing them until of uniform color, incorporating the coarse aggregate, adding water, and turning the entire mass at least three times, or until of uniform consistence.

As in the case of concrete sidewalk, concrete curb and gutter must be carefully protected after placing., and must be kept thoroughly wet for the first four days.

Precautions must be taken, when necessary, to protect from frost for a period of five days, and both the subbase and subgrade must be entirely free from frost at the time of placing the concrete.

The concrete should be mixed to a quaky consistence, so that water will flush to the surface under slight tamping. Mortar for the wearing course must be of such consistence that it will not require tamping, but can be easily spread into position.

All the above requirements are substantially the same as for the construction of concrete sidewalk.

Subgrade

The subgrade must be level, firm, and free from soft places. If filled, the earth must be tamped in layers not exceeding 6 inches in thickness. Whether a fill or an excavation, the surface must be finished 11 inches below the established grade of the gutter.

Subbase

Upon the subgrade must be laid the subbase consisting of suitable porous material, such as slag, cinders, large gravel, or broken stone, from which the finer pieces have been screened, and this material must be thoroughly compacted and rolled to a thickness of 5 inches, so that its surface will be 6 inches below the established grade of the gutter. The above measurements are given with reference to the grade of the gutter, which is itself 6 inches below the grade of the curb.

Construction

In combined curb and gutter, the depth of the back will be 12 inches, the depth of the face 6 inches, the breadth of the gutter from 16 inches to 24 inches, and the sections from 5 feet to 8 feet in length, with ½ inch expansion joints occurring every 150 feet. Expansion joints should be filled with tar, prepared felt, or other suitable material which will retain elasticity under changes of temperature, and the abutting corners should be rounded. The necessity for liberal expansion joints between the curb and the sidewalk deserves especial emphasis, as cases of concrete curb and gutter failing through lateral pressure from expanding sidewalk are numerous and unnecessary.

Two-inch lumber may be used for forms, except at street corners, where the radius should not be less than 6 feet, and may be provided for by substituting metal strips in place of the usual lumber. Metal cross-pieces must be provided between sections, and their position distinctly marked upon the front and back pieces of the forms in order that the wearing course, when applied, may be cut through and grooved exactly above the joint in the concrete base. The slope of the gutter may be regulated and maintained by using an ordinary wooden level with a nail driven in the bottom at one end, and extending out a distance equal to the required pitch.

The street side of the gutter will be raised at the approach to street-crossings, so that it may conform to the grade at the sidewalk crossing.

A number of very satisfactory varieties of forms are now manufactured from sheet steel. They are not only more durable than wood, but are held in place by templets, which do away with the necessity of cross-pieces and eliminate the clamps required in connection with wooden forms to hold in place the board forming the face of the curb. This is a distinct advantage, affording considerable saving of time, while the templets themselves satisfactorily divide the finished curb and gutter into sections, which is a point of considerable importance in view of the disaster which might otherwise follow a foundation failure.

Placing

In the construction of two-course concrete curb and gutter the concrete should be mixed in proportions of 1 sack of Portland cement, 2½ cubic feet of fine aggregate, and 5 cubic feet of coarse aggregate. Mortar for the wearing course should be mixed in the proportion of 1 sack of Portland cement to 2 cubic feet of sand or other suitable fine aggregate.

Concrete mixed in the proportions above specified should be deposited in the forms and thoroughly rammed to place, allowing ¾-inch for wearing surface, the latter to be applied as quickly as possible in order to secure an effective bond between the base and the wearing surface.

Three different methods of applying the wearing surface have been used. The first consists in applying the mortar to the top of the gutter and the top of the curb, and as soon as these have been finished, removing the form from the face of the curb and troweling the mortar down the vertical face. This method is unsatisfactory for several reasons. It often results in the face of the curb being but thinly covered, it necessitates the use of too dry a mixture on the vertical face, and results in excessive troweling which develops hair cracks and checking on the wearing surface. The second method consists in plastering on the inside of that portion of the form making the vertical face or street side of the gutter ¾ inch of plastic mortar, the form being filled with concrete at the same time, so that the introduction of the mortar and concrete is practically simultaneous. When the form lacks ¾ inch of being filled, the top is then filled with mortar. After removing the forms, the only work remaining is the finishing of corners. A 1½-inch radius is given to the curb on the street side and the intersection of the curb and gutter; all other edges are rounded to a ⅜-inch radius unless protected by metal. The third method differs from the second only in slipping a 1-inch board, 6 inches wide and surfaced on one side, inside of that portion of the form making the face of the curb. When the form has been filled with concrete this board is withdrawn, and the space left by its withdrawal is then filled with plastic mortar. The second method will usually secure a better bond between the base and the wearing surface.

Excessive troweling is too often practised in finishing the wearing surface of concrete curb and gutter. A large part of the finishing may be better accomplished by the use of a stiff fiber brush which will give a more durable surface, less likely to develop hair-cracks and checking.

One-course Work

Concrete curb and gutter has not yet been so extensively constructed after the one-course method as has one-course sidewalk, but one-course construction is likely ultimately to supersede, to a great extent, two-course, on account of greater durability, more permanent wearing surface, and the saving in time and labor. In one-course work the concrete should be prepared in proportions of 1 sack of Portland cement, 2 cubic feet of fine aggregate, and 3 cubic feet of coarse aggregate, using a tamper with pyramidal or similarly formed projections that will drive the coarse aggregate below the surface and leave the mortar on top for finishing with a wooden float.

III. Concrete Curb

In all cases where there is a probability of permanent road improvement concrete curb should be constructed without gutter, as the gutter will be provided by the slope of pavement adjoining the curb. By this method of construction the longitudinal joint separating the pavement from the curb is at the extreme edge of the pavement, and the objectionable longitudinal joint between pavement and gutter is eliminated.

Building concrete curb without gutter is very simple. There is no occasion for making the wearing surface richer than the main body of concrete; consequently the entire curb should be of 1:2:3 concrete finished with a wooden float, as recommended for one-course curb and gutter work.

For constructing concrete curb without gutter, the subgrade should be finished 30 inches below the established grade of the work. The subbase should occupy 6 inches, making its surface 24 inches below the established grade of the curb. Concrete curb should be 12 inches wide at the base, 6 inches wide at the top, 24 inches high, and have a batter on the street side of 1 to 4.

Laboratory Guide for an Elementary Course in Concrete Work

To aid instructors in planning and conducting an elementary course in concrete construction, the Association of American Portland Cement Manufacturers has prepared the outlines and suggested exercises which follow. As the course is now being given in a number of schools, four hours per week for thirty-six weeks are devoted to this work; but by condensing the outline and omitting some of the laboratory exercises, the time may be decreased about one-half, without entirely omitting any of the essentials of elementary theory and practice. An effort has been made to present the work in a logical progressive order, but the arrangement may be altered as seems necessary to meet particular requirements.

Scope of the Course

This course may be considered as divisible into four parts:

1. Class-room work, consisting of lectures and recitations.
2. Sketching and drawing.
3. Building forms and equipment.
4. Preparing, placing, curing, and testing the concrete.

What proportion of the total time available is to be given to each of these divisions will depend largely upon the features that the instructor desires to emphasize most; but in cases where the time available will not permit due attention to all parts of the work, sketching, drawing, and form building should be sacrificed rather than class-room work and practice in concreting.

In concreting courses of this kind now being taught elsewhere, about one-half of the total time is devoted to lectures, "shop talks," and recitations, these preceding the other work under each division head in the outline.

General Notes

Many instructors have found that the best results can be obtained by separating the class into groups of from three to six pupils. Articles to be made are classified in groups, and each student is given a choice of several exercises in each group. When a group of students has forms ready to fill and has calculated quantities of materials needed, one large batch of concrete is mixed by the group, from which all the forms are filled. This affords the students better practice than if each one were allowed to mix up only enough for some small flower-box or other exercise, although each student may mix his own batch when making test specimens.

Greater interest is likely to result if it is possible to make short trips of inspection to some practical concrete work in process. Saturday afternoons may well be taken up in this way, and the student given an opportunity to observe concrete work as it is carried on in actual practice, and have his attention called to examples of good and poor work. Local contractors and their foremen are generally quite willing to answer questions and explain their methods.

Most of the following exercises can be used in farm mechanics work, as well as in manual training courses. The primary object is to teach the elementary principles of concrete construction, and this must be borne in mind in the selection of exercises. At the start, simple and useful articles, instead of more elaborate pieces, are to be preferred, but as the course proceeds more complicated work may be undertaken. Artistic possibilities are limited only by the ingenuity of the students in designing and constructing the necessary forms.

Suggested Laboratory Instructions

Report on Laboratory Exercises

A written report should be required from each student for each exercise assigned. Students should provide themselves with note-books in which all data should be recorded. No credit should be given for reports not based upon the original data taken in the laboratory and entered in the laboratory note-book. Reports should be written in ink.

Reports should be turned in not later than one week after the exercise has been completed, and should be returned for corrections one week later. The form of report given below is suggested:

Report Sheet

Name...Date...

Title...

....

Object..

....

Hours' time spent on exercise...

Apparatus used...

....

....

Method of performing experiments...

....

....

....

Conclusions...

....

The drawings, descriptions, tables, and all calculations, together with answers to questions, should accompany the report sheet.

Suggested Exercises for Elementary Course in Concrete Construction

To be designed by the student:

1. Building blocks.
2. Horse block.
3. Duck pond.
4. Bird bath.
5. Concrete foundation.
6. Hotbed frame.
7. Small trough.
8. Rain barrel.
9. Stock tank.
10. Fish aquarium.
11. Outdoor swimming pool.
12. Ice-box.
13. Greenhouse.
14. Fence-posts.
15. Hitching-post.
16. Sun-dial.
17. Flower-box.
18. Garden-seat.
19. Lawn pedestal for flower urn.
20. Sidewalk tiles.

Equipment Required

In a number of schools a portion of the basement has been used for the concrete laboratory, but the room selected should have plenty of light and a smooth, level floor. Much of the work will naturally be done in the class-room and woodshop. Most of the following equipment can be made by the students in the woodshop classes:

1. A well-made mixing platform. It will be cheaper to build a good one at the outset than to waste time and money in constructing and using temporary ones. A suitable platform can be built of 2-inch lumber nailed upon three 4 by 4's rounded at the ends. The platform should have a surface at least 12 by 7 feet. The outside 4 by 4's project 6 inches at both ends of the platform, and are bored for clevis irons so that the platform may readily be dragged about.

BILL OF LUMBER FOR MIXING PLATFORM

12 pieces, 2 by 12 inch by 7 feet, dressed on one side and two edges (tongued and grooved preferred).
2 pieces, 2 by 2 inch by 12 feet, dressed on one side and two edges.
2 pieces, 4 by 4 inch by 13 feet, rough.
1 piece, 4 by 4 inch by 12 feet, rough.

2. Three measuring boxes holding 1 cubic foot, ½ cubic foot, and ¼ cubic foot, respectively, and preferably cubical in shape.

3. Two wood trowels, 4 by 8 inches, ½ inch thick. (See Plate No. 9.)

4. Tamper. (See Plate No. 9.) A tamper weighing between 15 and 20 pounds will be found suitable for school purposes. If made of pine, 8 by 8 by 12 inches or 8 by 8 by 18 inches is to be recommended, or if make of oak, 8 by 8 by 8 inches, would weigh approximately 20 pounds. A straight handle made of 1¼-inch galvanized pipe or wood will suffice.

5. Four small open bins for storing unscreened sand and gravel, crushed stone, screened gravel, and screened sand. (As only small quantities of aggregates will probably be kept on hand at any one time, the bins need hold only about ½ cubic yard.)

6. Water barrel.

7. Two or three water-buckets.

8. Wheelbarrow. (Preferably with a metal body.)

9. Two or more square-nosed shovels.

10. Screen for separating sand and gravel. (The best type of screen has longitudinal wires spaced ⅜ inch apart, with horizontal wires 4 to 6 inches apart to act as stiffeners. Common ⅜-inch square mesh will be found satisfactory, however.)

11. Curing tubs for exercises. (Such tubs can be made from oak oil barrels sawed in two.) Old turpentine barrels should not be used, the turpentine preventing the setting of the mortar or concrete.

Outline of the Course

I. Materials and Mixtures

1. Classroom Work.

(a) Cement, its qualities and how to handle and store it.

References:

"Lessons in Concrete," No. 1.

Bulletin No. 26, "Concrete in the Country," published by the Association of American Portland Cement Manufacturers.

General Notes:

The history of Portland cement and the details of its manufacture are interesting subjects to all, as is the matter of testing Portland cement to determine its fitness for our purposes. On the other hand, it must be remembered that a thorough knowledge of how to employ cement for our various purposes is much more important than a knowledge of its origin, and that tests on cement, unless conducted under standard laboratory conditions and by competent cement testers, are not reliable and mean but little.

Portland cement of any standard brand may be used without question, provided it has not been allowed to become lumpy in storage. In opening a sack it is well to run the hand down the inside in search of lumps. If there are particles present which will not crumble under the pressure of the fingers, the cement is unsuited for general use, although there may be no serious objection to using it in large foundations or other mass work after lumps have been screened out.

(b) Sand, gravel, and stone.

References:

"Lessons in Concrete," No. 2.
Bulletin No. 26, "Concrete in the Country."

General Notes:

The definitions of the common materials used in the work should be made clear to the students.

The term "aggregates" refers to sand, gravel, and stone for either mortar or concrete.

"*Fine aggregate*" is defined as "sand or crushed stone that will pass a No. 4 sieve; that is, a screen having four meshes to the linear inch."

"*Coarse aggregate*" is material such as "gravel and crushed stone that is retained on a No. 4 sieve." The largest particles in the coarse aggregate should never be larger than one-half the distance between the forms.

"*Bank-run gravel*" is the term applied to gravel and sand just as it is taken from the pit, without being washed or screened.

(c) Preparation, screening, washing, proportioning, and mixing.

References:

"Lessons in Concrete," No. 3.
Editorial, "Engineering Record," May 30, 1914.
"The Folly of Using Bank-run Mixtures in Concrete."

General Notes:

Screening.—Bank-run gravel should never be used as it comes from the deposit, but should be screened and then recombined in the proper proportions. Strong, dense, water-tight concrete requires strict attention to proportioning. This precludes the possibility of using bank-run material without screening.

Water Used.—Water used must be clean, free from oil, acid, alkali, and vegetable matter.

Proportioning.—In proportioning by volume, a sack of cement is considered as one cubic foot, and by weight, a sack of cement may be accepted as 94 pounds net. Materials should always be carefully measured, never guessed at. On large jobs it is customary to measure aggregates in multiples of "one-sack batches." One cubic foot, the sack of cement, is taken as the unit of measure. The aggregates are then proportioned with suitable sizes of measuring boxes varying in capacity from 1 to 3 cubic feet.

(d) Theory of mortar and concrete.

References:

Bulletin No. 26, "Concrete in the Country," p. 11.

General Notes:

The aggregates consisting of sand and gravel or broken stone are wholly inert until combined with Portland cement. Consequently, it is of prime importance that every grain of sand be enclosed in a film of cement and water and every piece of coarse aggregate be surrounded with cement mortar.

The following table will be found very useful in calculating the quantities of sand and gravel, or stone, required for a one-bag batch of mortar or concrete, and in computing the volume of the resulting mortar or concrete.

TABLE NO. 1

Mixtures			Materials			Vol. in Cu. Ft.	
Cement	Sand	Gravel or Stone	Cement in Sacks	Sand Cu. Ft.	Gravel or Stone Cu. Ft.	Mortar	Concrete
1	1.5	..	1	1.5	..	1.75	..
1	2.0	..	1	2.0	..	2.1	..
1	2.5	..	1	2.5	..	2.5	..
1	3.0	..	1	3.0	..	2.8	..
1	1.5	3	1	1.5	3	..	3.5
1	2.0	3	1	2.0	3	..	3.9
1	2.0	4	1	2.0	4	..	4.5
1	2.5	4	1	2.5	4	..	4.8
1	2.5	5	1	2.5	5	..	5.4
1	3.0	5	1	3.0	5	..	5.8

TABLE NO. 2

QUANTITIES OF CEMENT, SAND, AND GRAVEL OR STONE REQUIRED FOR ONE CUBIC YARD OF COMPACT MORTAR OR CONCRETE

Mixtures			Quantities of Materials				
				Sand		Stone or Gravel	
Cement	Sand	Gravel or Stone	Cement in Sacks	Cu. Ft.	Cu. Yd.	Cu. Ft.	Cu. Yd.
1	1.5	..	15.5	23.2	0.86	..	..
1	2.0	..	12.8	25.6	0.95	..	..
1	2.5	..	11.0	27.5	1.02	..	..
1	3.0	..	9.6	28.8	1.07	..	..
1	1.5	3	7.6	11.4	0.42	22.8	0.85
1	2.0	3	7.0	14.0	0.52	21.0	0.78
1	2.0	4	6.0	12.0	0.44	24.0	0.89
1	2.5	4	5.6	14.0	0.52	22.4	0.83
1	2.5	5	5.0	12.5	0.46	25.0	0.92
1	3.0	5	4.6	13.8	0.51	23.0	0.85

Stone and gravel = 45 per cent. voids (average).
1 sack cement = 1 cu. ft.; 4 sacks = 1 bbl.
Based on tables in "Concrete, Plain and Reinforced," by Taylor & Thompson.

It is necessary occasionally to mix up quantities of concrete or mortar requiring less than a sack of cement, and for small exercises some other unit of proportioning than the cubic foot is necessary. A quart measure, which holds approximately 2¾ pounds of cement, or a peck measure, which holds approximately 22 pounds, will be found very convenient for measuring small quantities of cement. When dumped from the sack, cement becomes fluffy and occupies more space than when compacted in a sack; hence in measuring cement by volume it will be found necessary to jar it down a few times in the measure in order to get accurate results. Both coarse and fine aggregate can be measured by means of small measuring boxes holding ¼, ½, and 1 cubic foot respectively; or by the quart or peck measure referred to above.

TABLE NO. 3

1:2 Mixture	1 sack cement 94 lbs.	2 cu. ft. sand
	47 "	1 " " "
	32 "	⅔ " " "
	23.5 "	½ " " "
	16 "	⅓ " " "
	12 "	¼ " " "
1:3 Mixture	1 sack cement 94 "	3 " " "
	47 "	1½ " " "
	32 "	1 " " "
	23.5 "	¾ " " "
	16 "	½ " " "
	8 "	¼ " " "

Mixing

The first step in mixing is to spread the sand in a thin layer over the center of the mixing platform, then spread the cement on top of the sand

and mix together dry, continuing the turning until the color is uniform and without streaks. After the cement-sand mixture has been turned at least twice it should be spread in a thin layer and the measuring box placed upon it. The proper amount of screened gravel should then be shoveled into the box and the latter lifted off. Mixing is then continued until the gravel is thoroughly distributed throughout the mass; this will require turning the batch at least twice. Water is then added slowly from a sprinkling can or from a small stream applied by a hose, the mixing continued until all parts of the mass are the same in color and consistence and wet enough so that there is a tendency to flatten out when the mass is heaped up. The concrete must always be used within twenty minutes or half an hour after the water has been added.

The quality of the concrete depends largely upon the amount of water in the mixture, a mixture such as described giving better results than a dry one; in fact, a dry mixture is not capable of developing all the strength of the cement. Mixtures containing less water are frequently used in making cement products, but the practice is a bad one and should be avoided whenever possible. Too much water is likely to cause pockets and imperfections in the surface of the work, and increases shrinkage while hardening.

II. Forms and Molds

1. Class-room Work. (Using slides or charts.)

(a) Materials for making.

References:

"Lessons in Concrete," No. 4.
Bulletin No. 26, "Concrete in the Country."
Bulletin No. 23, "Concrete Tanks."

General Notes:

Forms are made of wood, metal, and combinations of wood and metal.

(b) Various types.

References:

Same as those given under (a).

General Notes:

Various types of forms.

1. Rectangular forms wholly of lumber.
2. Rectangular forms using metal fastening.
3. Rectangular metal forms.
4. Circular forms of wood and sheet metal.
5. Circular forms wholly metal.
6. Miscellaneous.

(c) General requirements, care, and use.

References:

Same as those given under (a).

General Notes:

Green lumber will keep its shape better in all rectangular forms than will lumber that is thoroughly dry. If dry lum-

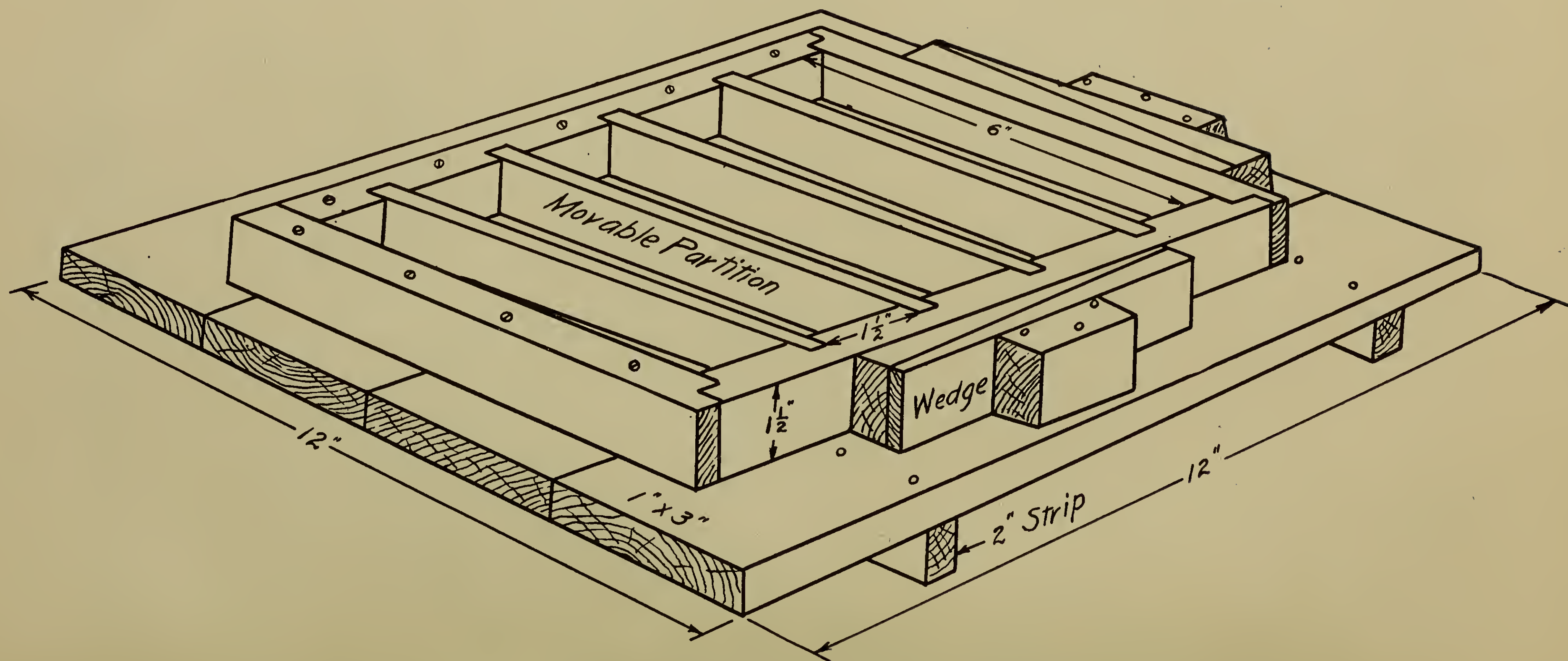


Plate 1.—Assembled Form for Concrete Test Specimens.

ber is used, it should be thoroughly wet before the concrete is placed. White pine is considered the best lumber for forms, although spruce, fir, and Norway pine are often used. The face of the forms should be free from knots, slivers, or other irregularities. The forms should be thoroughly cleaned each time they are used, so that no dry concrete is left sticking to the face of the forms. The use of oil or grease on the face of forms is recommended, as it prevents absorption of water from concrete and makes form removal easier. A mixture of equal parts of boiled linseed oil and kerosene is generally used for painting the forms. Tallow or animal fats should not be used in painting the forms.

2. Form Work.

Construction, small wooden molds for making test specimens.

EXERCISE I-A

GANG MOLD FOR TEST SPECIMENS

(Plates Nos. 1 and 2)

The construction of a small wooden gang mold for making test specimens 1½ inches square and 6 inches long.

Tools used: Saw, plane, square, gauge and hammer.

MILL BILL OF MATERIAL FOR GANG MOLD

4 pieces	1 inch	x 3 inches	x 12 inches	S3S, base of form.
2 pieces	¾ inch	x 1½ inches	x 10½ inches	S2S, sides of form.
2 pieces	¾ inch	x 1½ inches	x 8 inches	S2S, sides of form.
4 pieces	¼ inch	x 1½ inches	x 6½ inches	S4S, movable partitions.
2 pieces	2 inches	x 2 inches	x 12 inches	S1S, bottom strips.
2 pieces	2 inches	x 1½ inches	x 3 inches	S4S, blocks.
2 pieces	2 inches	x 1½ inches	x 5 inches	S4S, wedges.

(See "General Notes" for instructions to be followed in selecting the lumber for wooden forms.)

The joints of the mold should be as tight as possible. This will require care and accuracy in squaring up the various pieces before they are assembled.

As shown in the assembled drawing of the small gang mold, the first thing to consider would be the base of the form, which will be made either of four 1 by 3 inch strips or two 1 by 6 inch boards held in place by 2-inch strips which can be made by cutting 2 by 4's lengthwise. All pieces should be squared up and surfaced with a plane before they are put together.

The sides of the form can be made from strips 1 inch thick and 2 inches wide, planed down to ¾ inch thick by 1½ inches wide and supplied with grooves as shown. The four movable partitions are made from ¼-inch stock, and the ends are slightly tapered so that they can be moved in their respective grooves without difficulty.

Two of the sides of the form are fastened securely to the base by means of screws, and the other two sides are held in position by means of wedges, which can easily be made by sawing a block in two diagonally. After all the pieces have been approved by the instructor and the form has been assembled, the faces which will come in contact with the concrete should be given two coats of shellac.

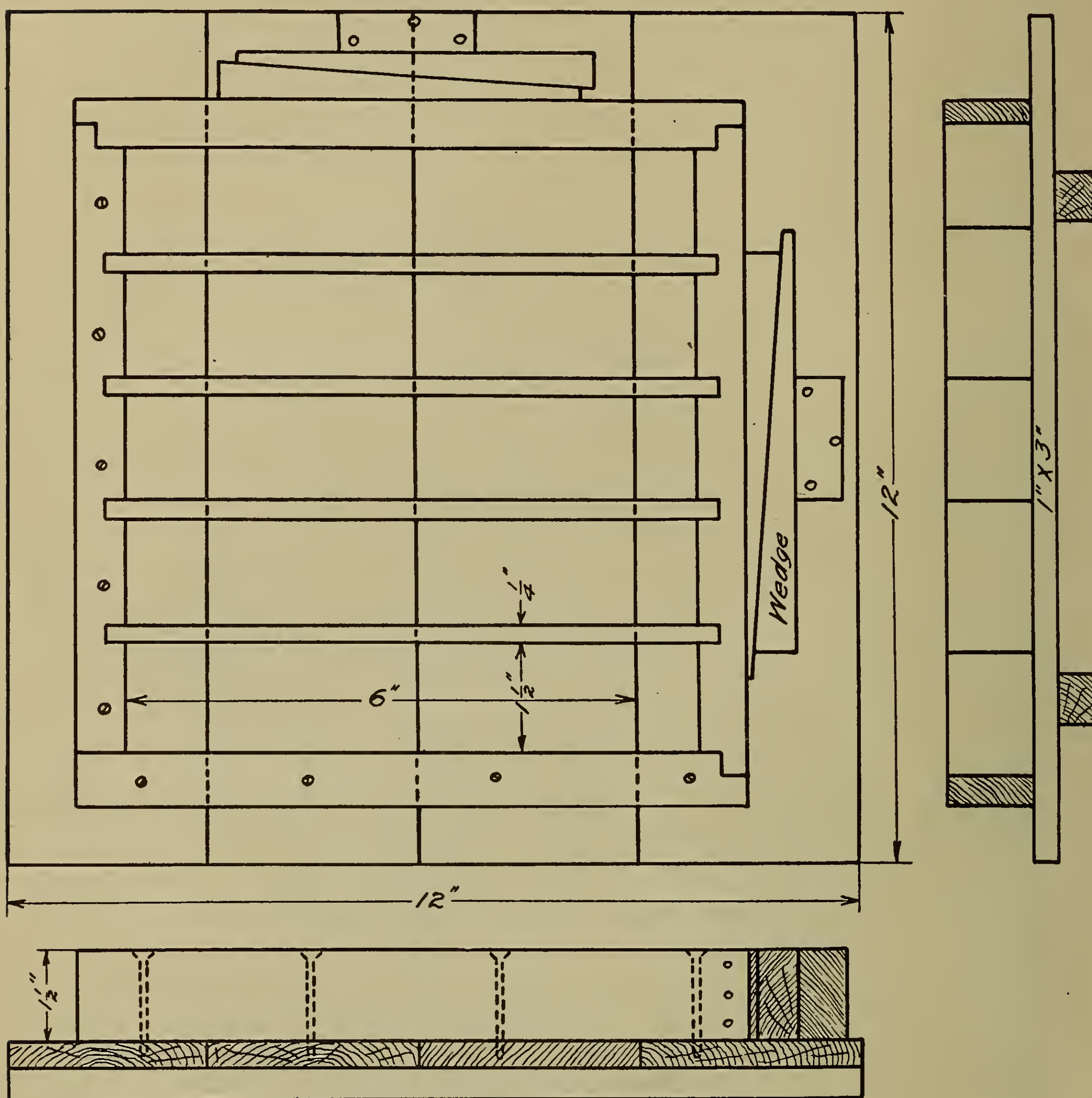


Plate 2.—Details of Form for Test Specimens.

Exercise I-B (Optional with Exercise I-A)

Gang Mold for Test Specimen

(Plate No. 3)

The construction of this gang mold is much more simple than that described in Exercise I-A, and is preferable for work with younger

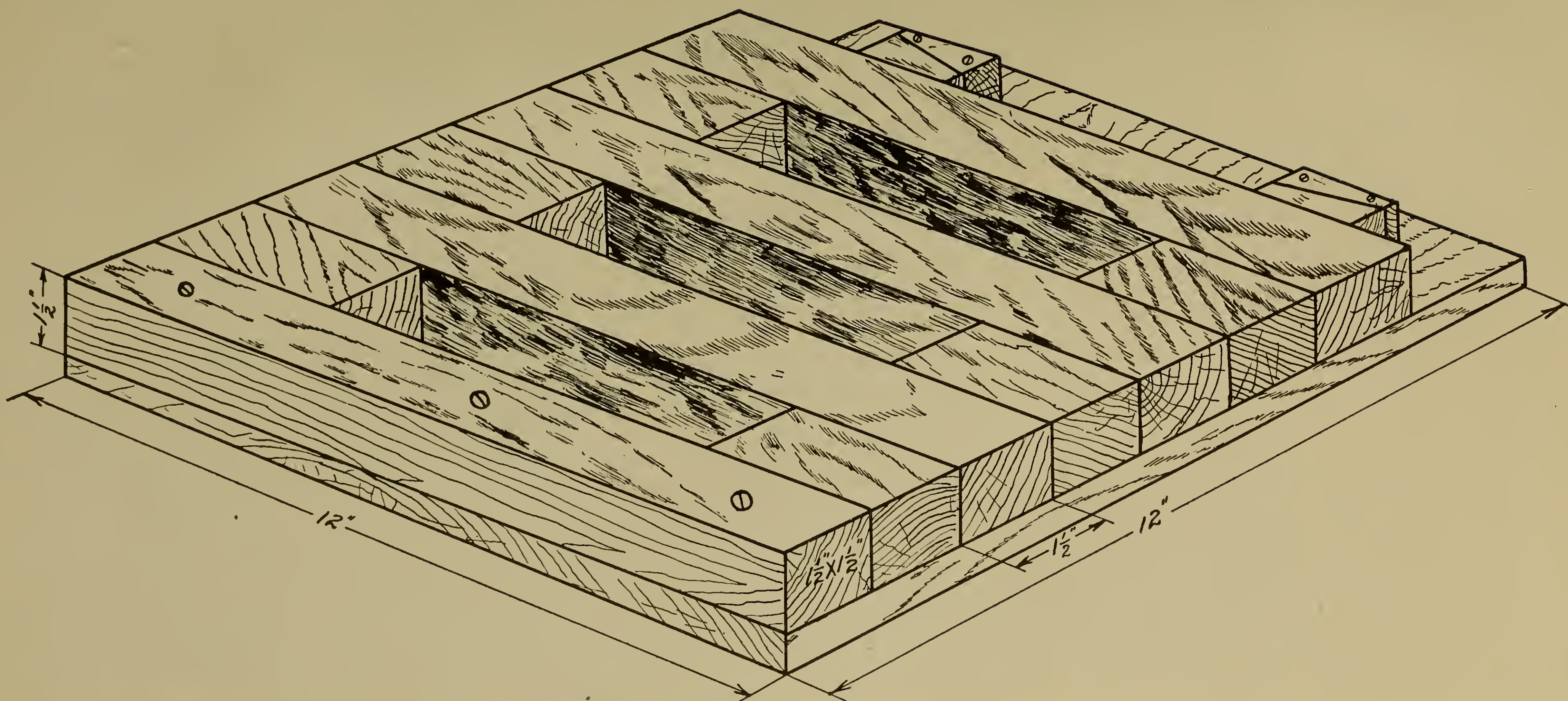


Plate 3.—Assembled Form for Concrete Test Specimens.

boys. As shown on the plate, it is only necessary to cut and plane to size four strips 1½ by 1½ by 12 inches and six blocks 1½ by 1½ by 3 inches. One of the longer strips is fastened securely in position by means of three screws; all other parts of the mold are movable except the blocks that hold the wedges. The form is designed for molding three test specimens of the same size as those made in mold I-A.

III. Tools and Equipment

1. Class-room Work. (Using slides and charts.)

   (a) List of the common tools.

   Reference:

   Bulletin No. 26, "Concrete in the Country."

   General Notes:

   Common Tools.—Shovels, pails, tamper, float, edger trowel, groover, and straightedge.

   Equipment.—Screen, mixing platform, measuring box, wheelbarrow, water barrel.

   (b) Directions for constructing floats, wooden trowels, tampers, straightedge, mixing platform, and mixing box.

   Reference:

   Bulletin No. 26, "Concrete in the Country."

   General Notes:

   For size, see accompanying drawings and general directions. Blackboard sketches will be found helpful in explaining the various tools and equipment.

2. Woodshop Work.

   (a) Making a straight edge, float, wood trowel, measuring box, tamper, etc.

Exercise 2-A

A Device for Testing Small Concrete Specimens

(Plate No. 4)

This simple device for testing small concrete specimens can easily be made by elementary manual training students. It is intended for use only in testing very small beam specimens, and even for such work much more satisfactory results can be accomplished by the use of the home-made testing machine shown in Plates Nos. 5 and 6.

The testing device consists of two triangular pieces of hardwood 18 inches long, which can be clamped to any ordinary bench or table. The distance apart will, of course, depend upon the length of the specimens to be tested. The specimen should bear on the points at a distance of about ½ inch from each end, and the triangular supports should always be kept exactly parallel.

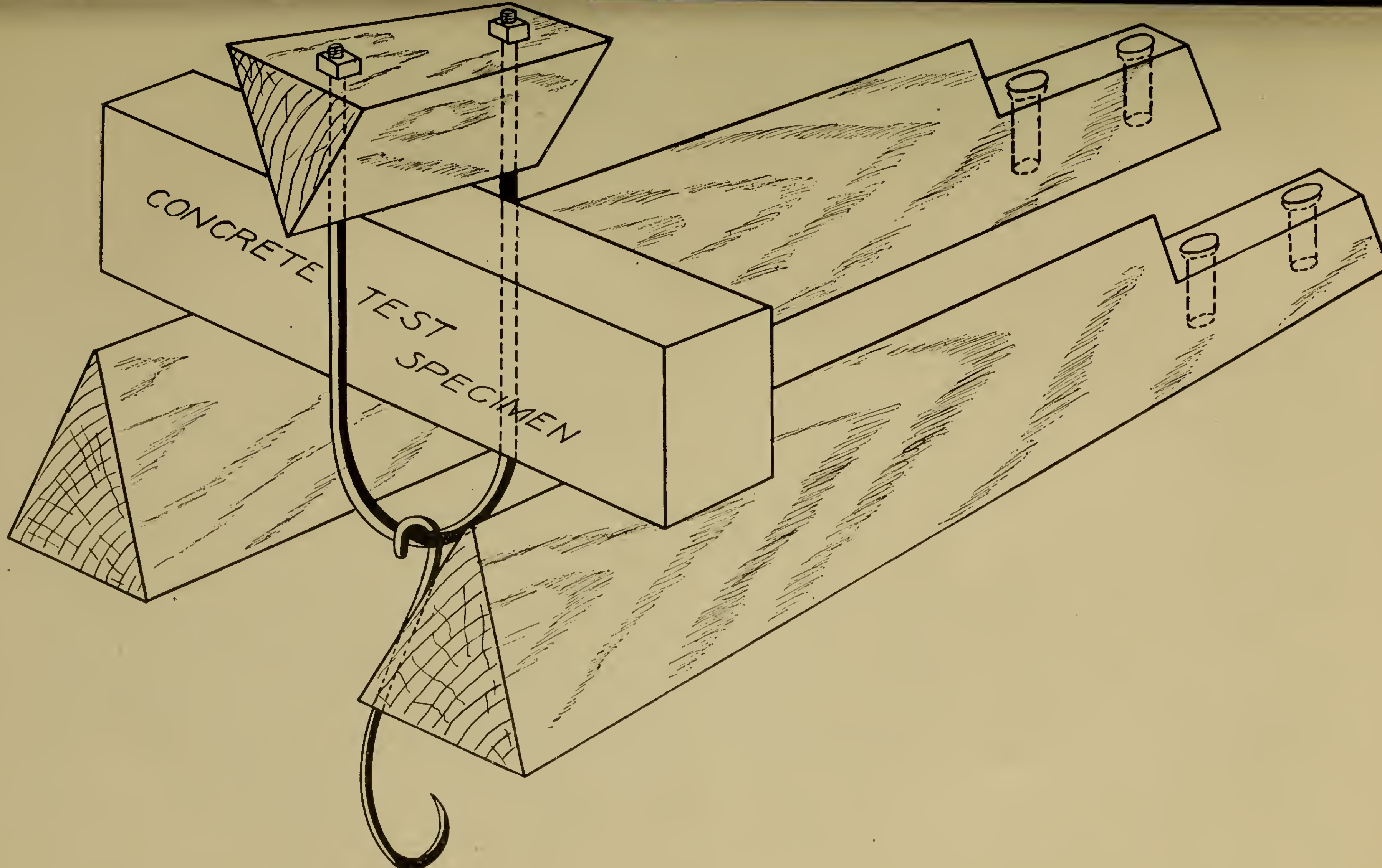


Plate 4.—Device for Testing Small Concrete Specimens.

The loads are applied by adding sand or water, preferably the former, to a pail suspended by a hook secured to a third triangular piece or saddle resting across the specimen at the center. Sand used should be fine and thoroughly dry, so it will readily flow through a small rubber tube connected to a can or funnel, the flow being shut off by a pinch-cock fitted to the tube.

Exercise 2-B

Testing Machine

(Plates Nos. 5 and 6)

This small, home-made machine was designed by the Muncie (Indiana) Normal Institute for testing specimens either 1 by 1 by 12 inches or 1 by 2 by 12 inches.

It consists of levers so arranged that the load applied to the specimen is increased ten times over that applied to the machine. It is equipped with an automatic cutoff, which prevents the load from increasing after the specimen has failed.

The frame which supports the machine can be made of pine, but the lever arms should be of hard wood. One end of the lower lever supports a can, which is located just below another can containing a supply of dry sand. At the other end of the lever a ball weight is suspended which can be adjusted so as to balance the levers just before the test is applied.

At the center of the bottom of the can containing the sand is a ½-inch hole through which the sand is allowed to flow into the lower box. An automatic cutoff controlled by a coiled spring and trigger is provided. A No. 9 wire is attached to the lower lever and projects through a small opening in the cutoff, when the large hole in cutoff is directly under the opening in the sand supply can. This wire acts as a trigger, and as the beam breaks and the levers descend, the wire is withdrawn from its hole, releasing the cutoff, which in turn is drawn back by the spring cutting off the supply of sand. The weight of the sand in the lower can is determined and multiplied by ten. This product will give the load which caused the specimen to fail.

IV. Walk and Floor Work

1. Class-room Work.

   (a) Equipment for concreting.

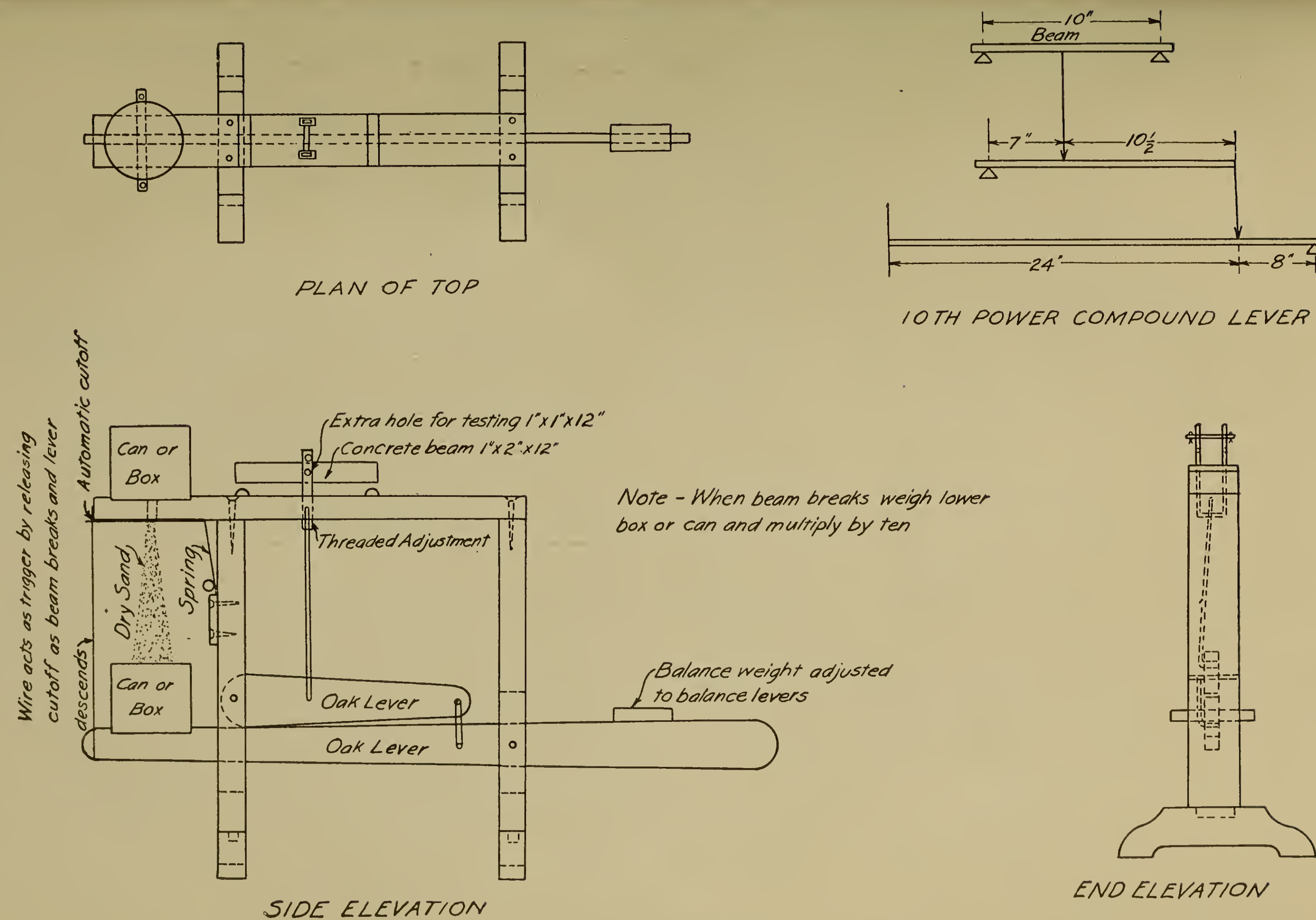
   Reference:

   "Lessons in Concrete," No. 8.

   General Notes:

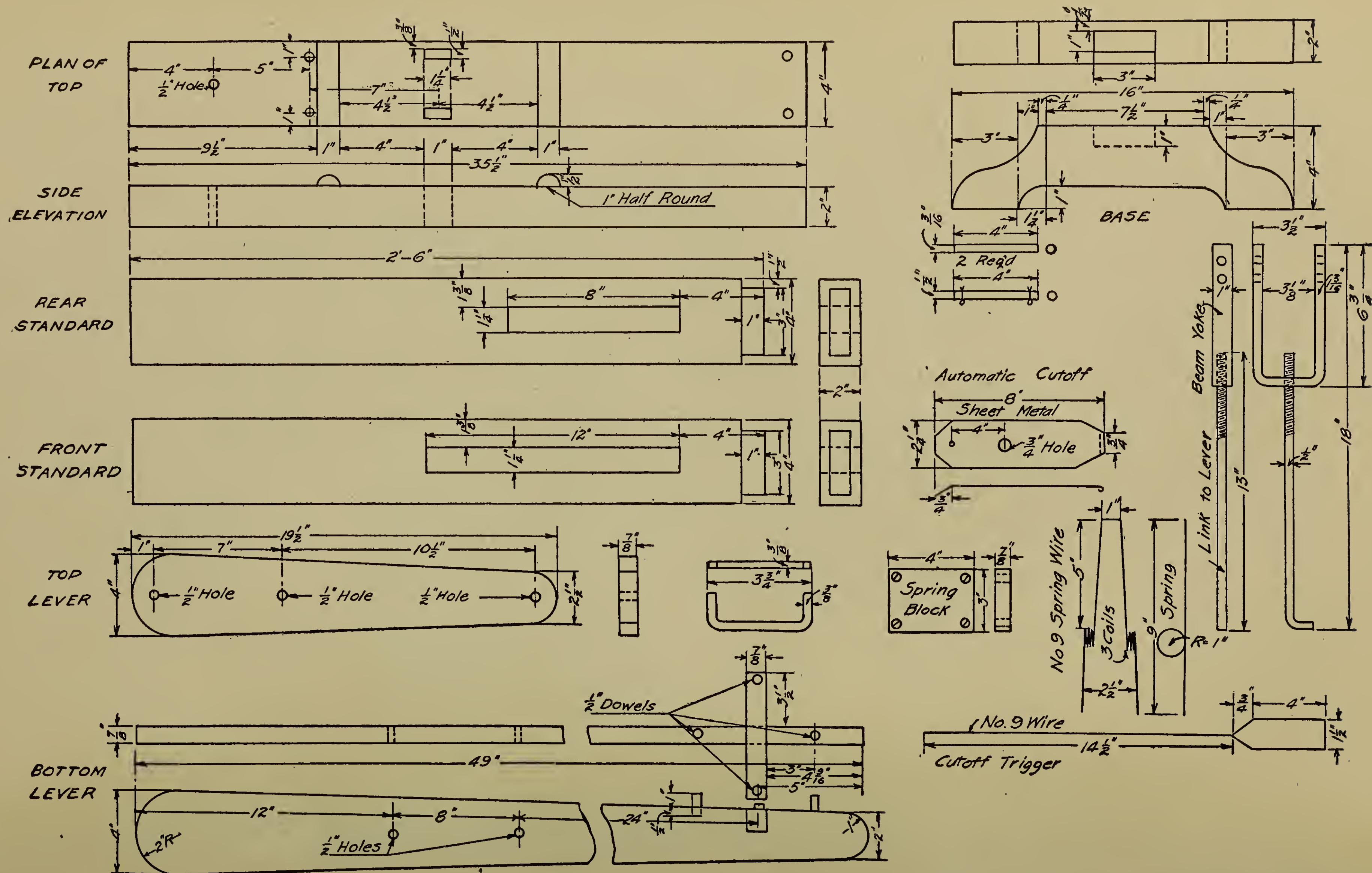
   The equipment necessary is as follows: Mixing platform, measuring box, screen, trowels, straightedge, tamper, float, wheelbarrow, water barrel, shovels, and pails.

   (b) Forms for flat concrete work, sidewalk, and floor slabs.



Designed by the Muncie Normal Institute, Muncie, Ind.

PLATE 5.—CEMENT TESTING MACHINE.



Designed by the Muncie Normal Institute, Muncie, Ind.

PLATE 6.—DETAILS OF CEMENT TESTING MACHINE.

6

81

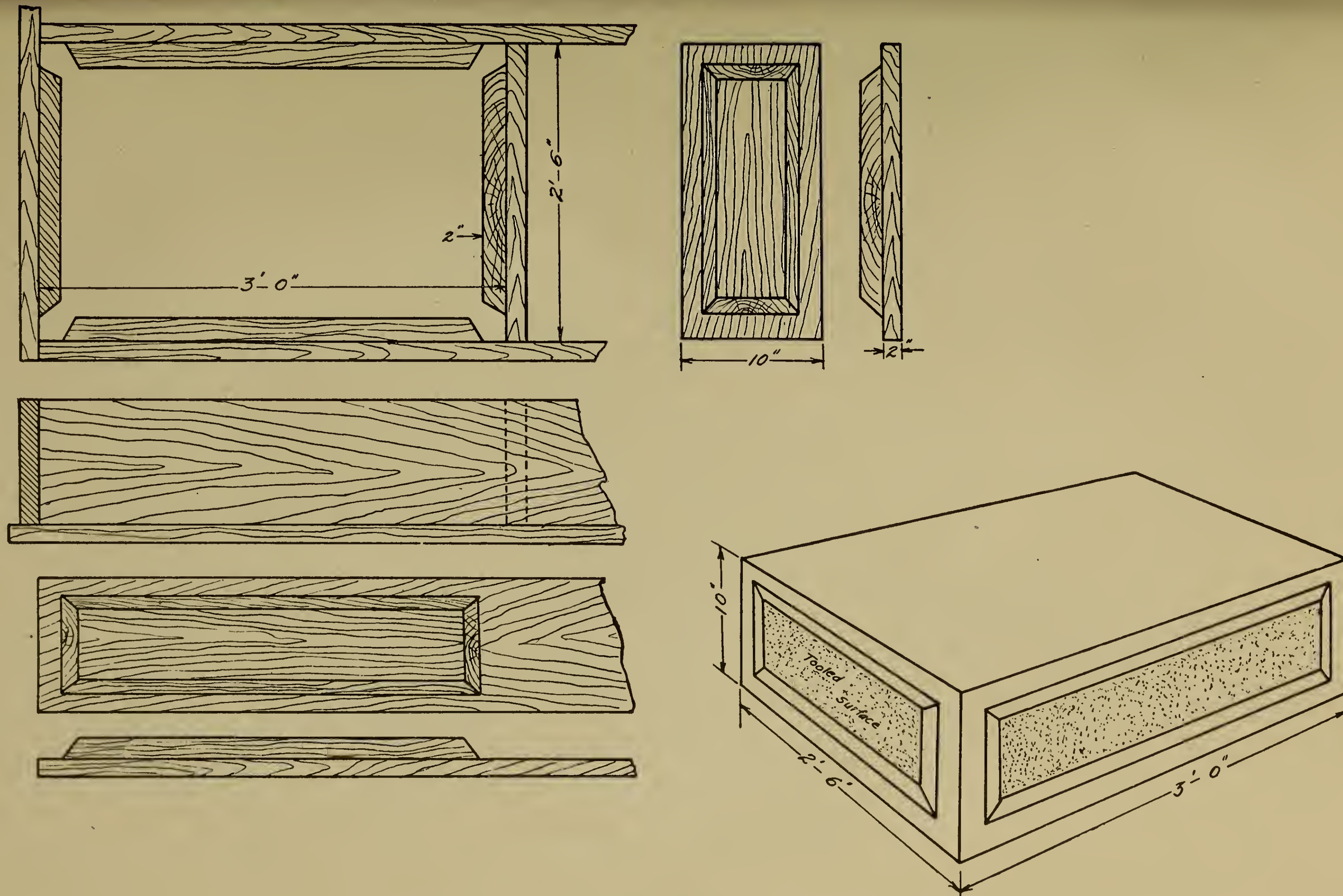


PLATE 7.—DETAILS OF CONCRETE HORSEBLOCK FORM.

References:

Published lectures: "Concrete Walks, Floors and Pavements."

Bulletin No. 26, "Concrete in the Country," pp. 28–34 inc.

General Notes:

See accompanying Plate No. 9 showing one-course and two-course walks and the tools used in constructing them.

(c) Concrete walk and floor construction.

Reference:

Bulletin No. 26, "Concrete in the Country."

"Lessons in Concrete," No. 6. "Concrete Surfaces."

2. Form Work.

(a) Construction of forms for any of the following: Sidewalks, horse blocks, curbs, dairy barn floor, monolithic steps.

(b) Exercise in finishing concrete surfaces with wood and steel trowels, noting the effect of excessive troweling with steel trowel, which brings the cement and finer particles to the surface.

Exercise 3

Form for Concrete Horseblock

(Plate No. 7)

Tools necessary for constructing the form: Saw, plane, try square, gauge, hammer.

BILL OF MATERIAL

2 pieces 2 inches x 10 inches x 3½ feet
1 piece 2 inches x 10 inches x 2½ feet
1 piece 2 inches x 10 inches x 2 feet 8 inches
2 pieces 2 inches x 8 inches x 2½ feet
2 pieces 2 inches x 8 inches x 2 feet

Before assembling the mold, each piece should be oiled thoroughly on both sides with linseed oil, as well as on the ends. This will also prevent any tendency of the mold to warp or buckle.

Exercise 4

Concrete Porch and Step Construction

(Plate No. 8)

Tools necessary for constructing the form: Saw, square, hammer.

The accompanying plate is self-explanatory. The same precautions should be taken as described in connection with all wooden forms as to selection of lumber and oiling, so that the form can be removed easily. It is possible to construct the form using stock lengths, and the plank can again be used for other forms.

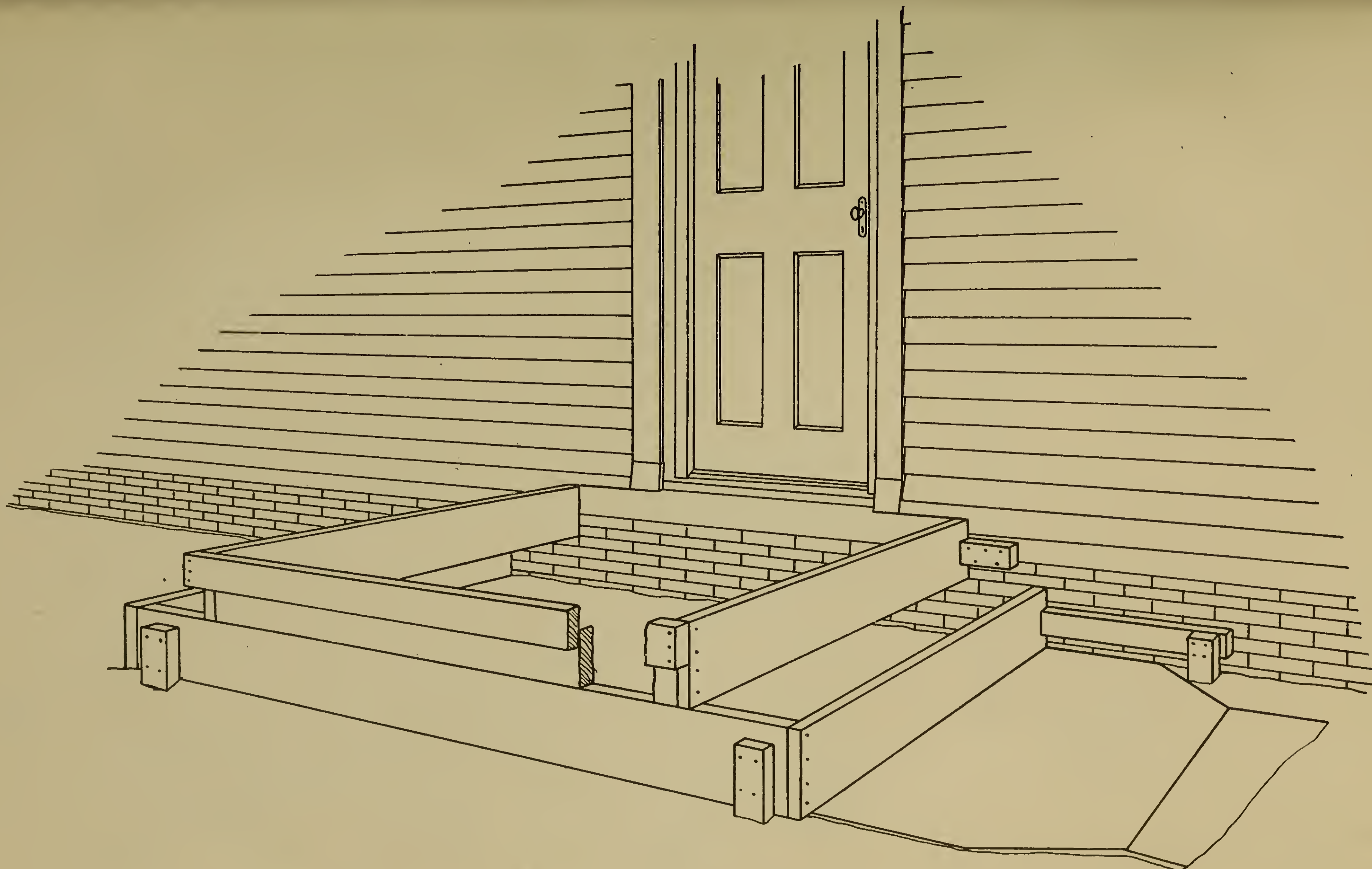


Plate 8.—Details of Concrete Step and Porch Construction.

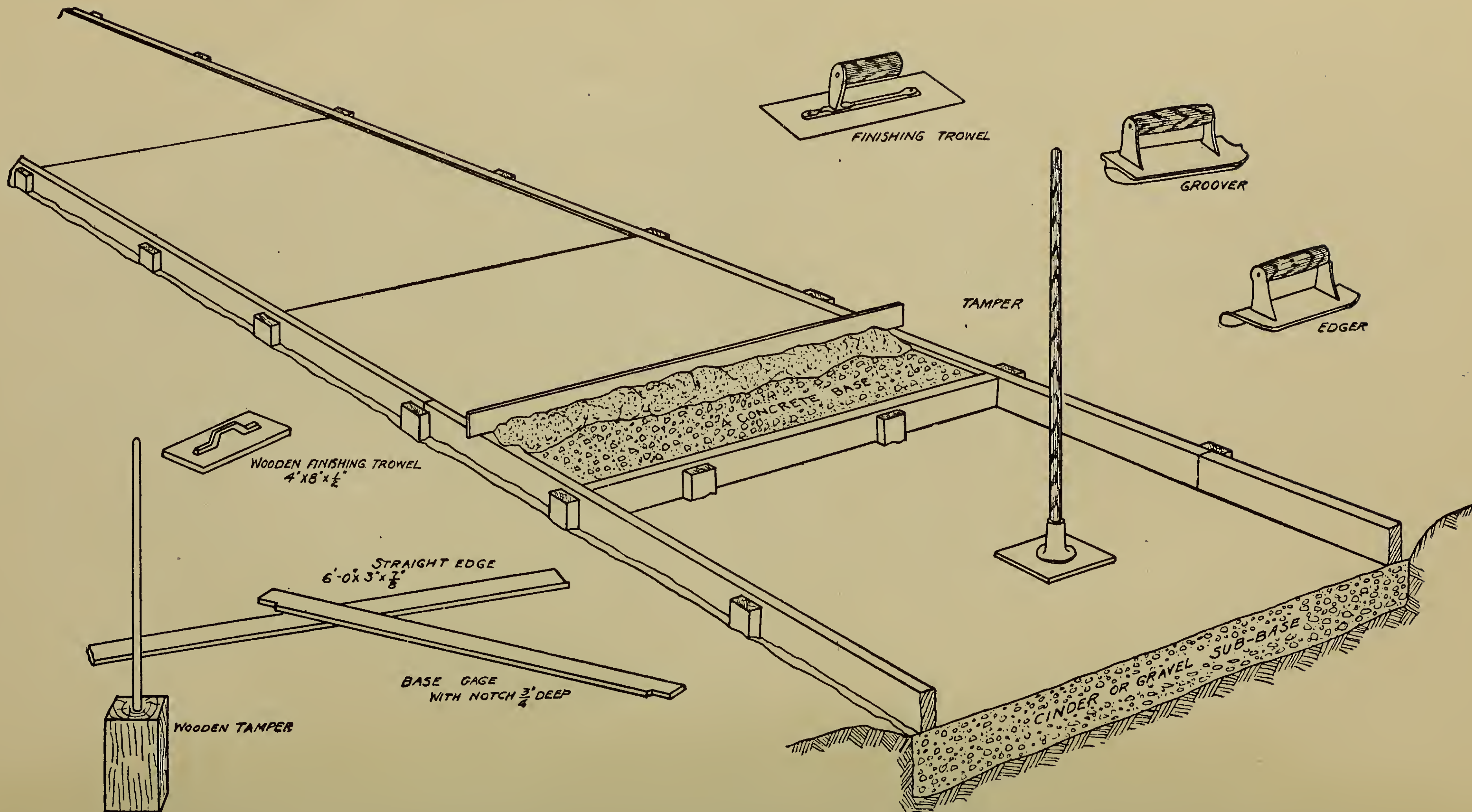


PLATE 9.—DETAILS OF CEMENT SIDEWALK CONSTRUCTION.

Exercise 5

Details of Cement Sidewalk Construction

(Plate No. 9)

Tools necessary for constructing form: Ax, saw, hammer.

2 by 4 or 2 by 6 inch lumber should be used for the forms, except for curves, where common house siding or other thin lumber (or sheet metal) will be found convenient.

Forms of 2 by 4 inch stuff should be used for a walk 4 inches thick and 2 by 5 inches for walks 5 inches thick.

3. Concrete Work.

Construction of horseblock; steps, sidewalk.

V. Elementary Theory of Reinforcement

1. Class-room Work.

(a) Definition of tension and compression.

References:

"Concrete Plain and Reinforced," Taylor and Thompson.
"Reinforced Concrete Construction," Vol. I, Geo. S. Hool. Published by McGraw Hill Publishing Company, New York City.

General Notes:

Concrete is a material which is strong in compression, or crushing strength, but, like other masonry, is weak in resisting tension or pulling force; therefore it must be reinforced with steel, which is strong in tension.

(b) Reinforcing materials.

References:

"Concrete Plain and Reinforced," Taylor and Thompson.
"Reinforced Concrete Construction," Geo. S. Hool.

General Notes:

Suitable materials: Steel rods—round, square, and twisted square, or of special section, providing they have a sufficient cross-sectional area. Woven-wire fabric especially made for reinforcing, wire cables, and similar reinforcing are used extensively.

(c) Most efficient placing of reinforcement in simple exercises.

General Notes:

Care must be taken to place the steel reinforcing where it will do the most good, and this, of course, will depend upon the loads, point of application, etc. For instance, a fence post will be subject to different stresses and strains than would a beam supported at both ends with the load applied transversely; and a slab in a vertical position, as in a wall, will be subject to different strains than one in a horizontal position. A few blackboard sketches will help bring out some of the elementary principles of reinforcing.

VI. Unit Construction

1. Class-room Work.

   (a) Forms for unit work; reinforcing; assembling.

   References:

   "Reinforced Concrete Construction," Vol. II, G. S. Hool.

   General Notes:

   Often, in the use of concrete in building construction, various parts of the structure are cast as units, such as wall sections, posts and columns, and when properly hardened are assembled to form the structure.

   (b) Designing pedestals, sun-dials, garden-seats, plates for baseball diamonds, and other unit exercises mentioned on page 66.

   References:

   See plates Nos. 10 and 11.

   General Notes:

   There are many small articles that can be designed by the student, such as foot-scraper, door-weight, small tile, home-plate for baseball diamond, etc.

2. Concrete Work.

   (a) Construction of unit dog-house; a flight of unit steps; pedestal; garden-seat, etc.

Exercise 6

Lawn Pedestal

(Plate No. 10)

There are three simple designs shown on the plate which lend themselves nicely to the material. Forms in which to cast them are easily constructed.

A 1:2 mixture of cement and sand is to be recommended, though in some cases a 1:3 mixtures might be found satisfactory. Various surface effects can be secured by using marble or granite screenings, ground mica, or combinations of two or more different aggregates. A little experimenting with available aggregates will soon show the variations in color possible without resorting to the use of artificial coloring. (Under the heading Colored Surfaces, additional information is given on this subject.) Scrubbing the surface of green concrete in which variegated colored aggregates have been used will result in decidedly pleasing effects.

Exercise 7

Garden Bench

(Plate No 12)

The plate shows plainly the construction of the forms and the method of reinforcing.

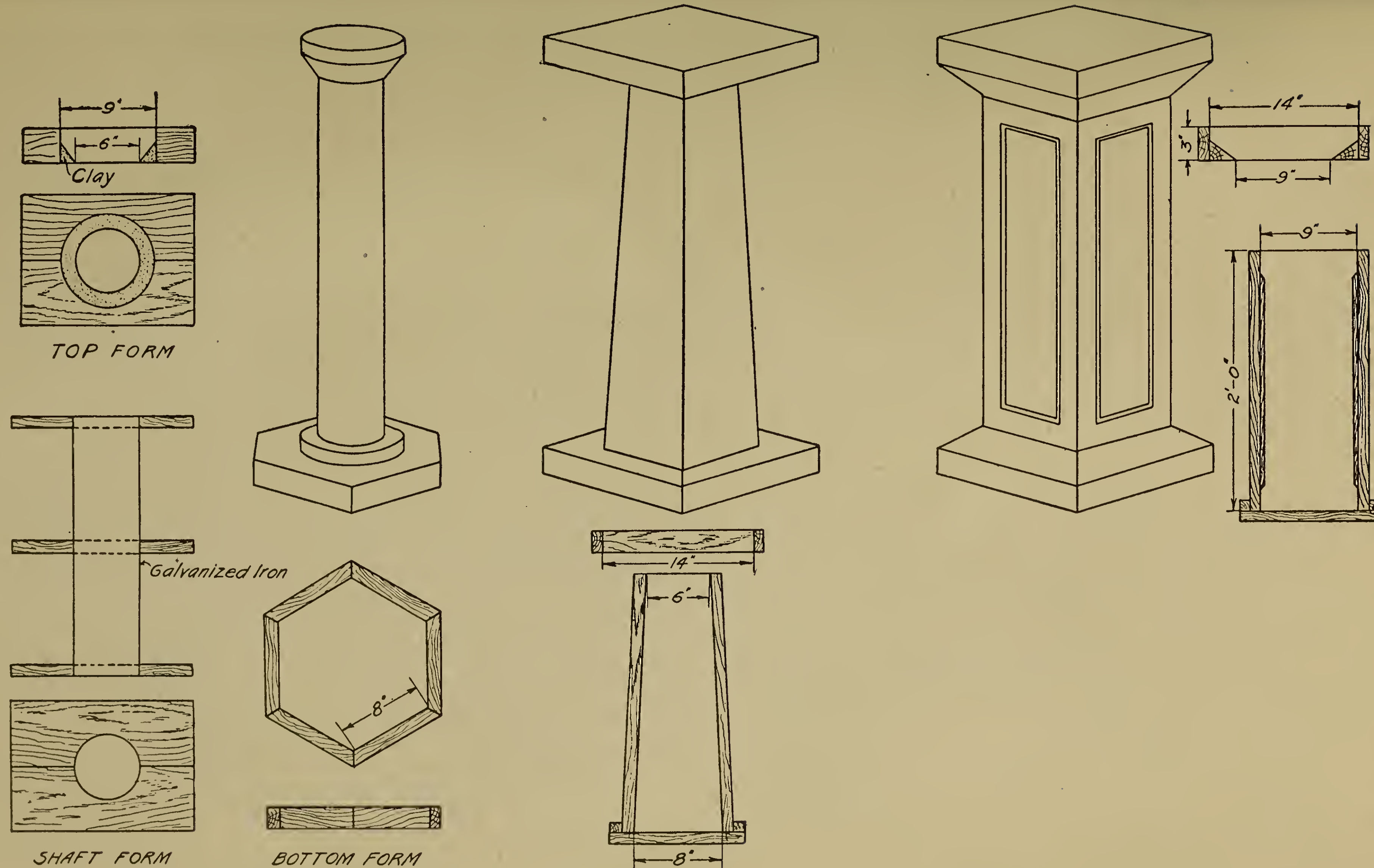


PLATE 10.—DESIGN OF CONCRETE PEDESTALS.

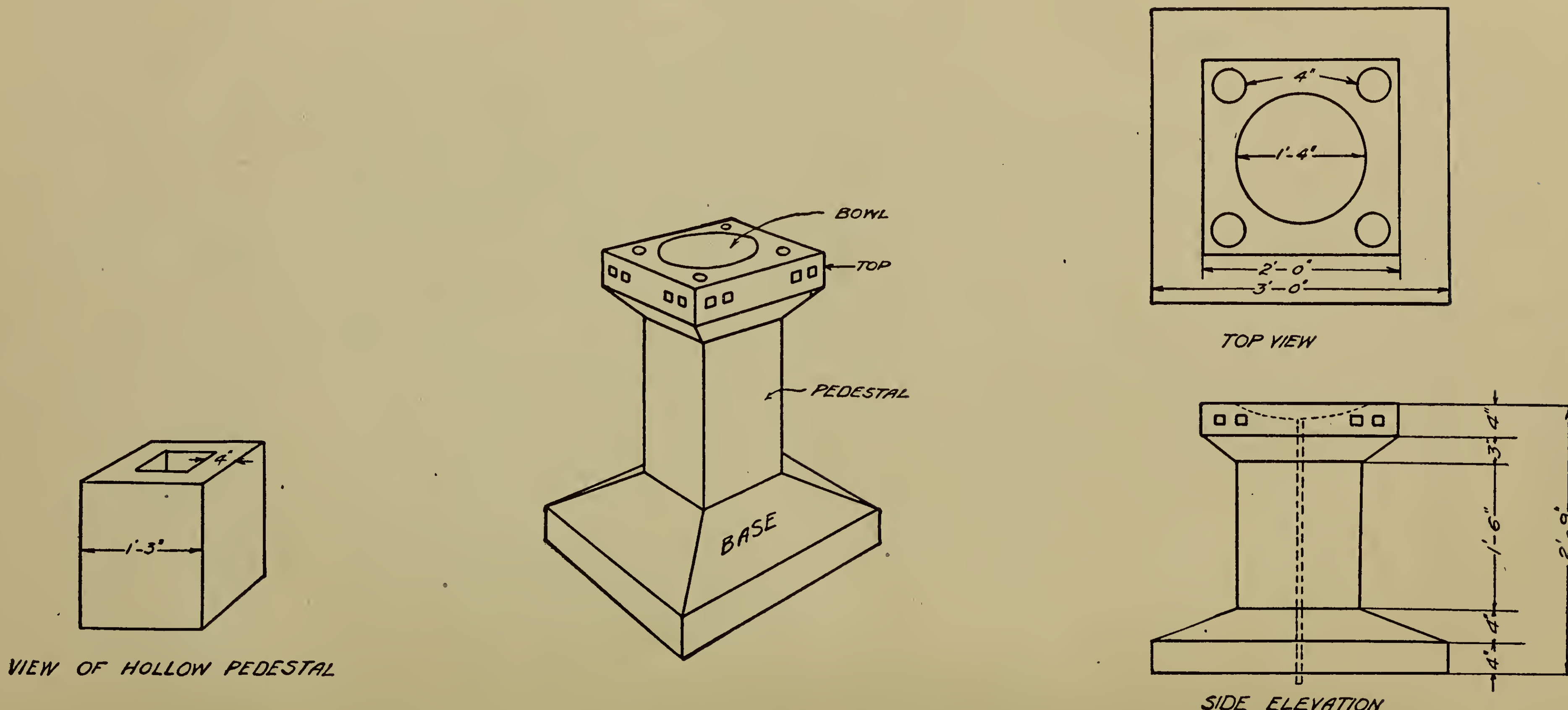


PLATE 11.—CONCRETE BIRD BATH.

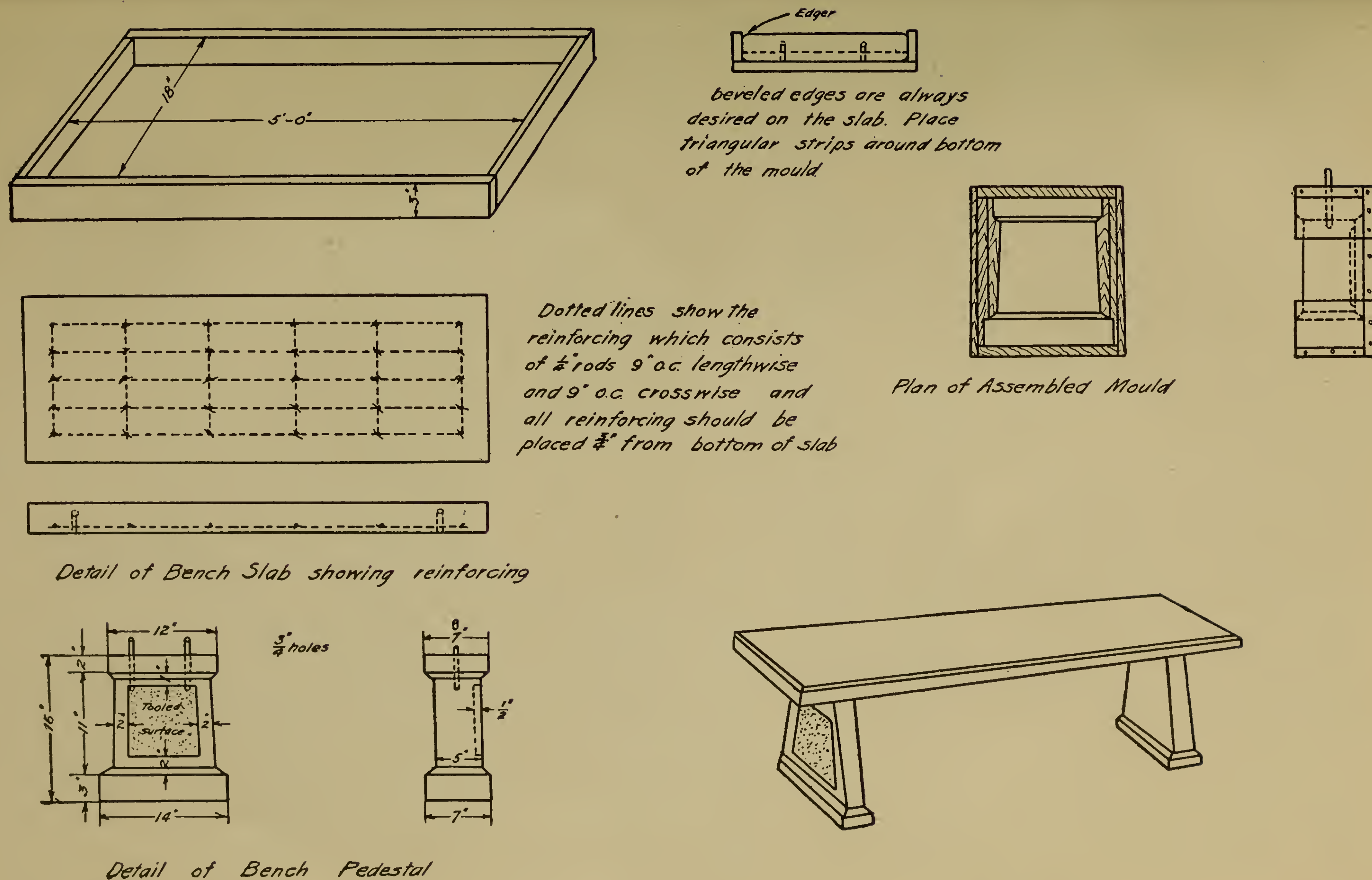


PLATE 12.—SIMPLE GARDEN BENCH.

The concrete mixture should be composed of 1 part Portland cement, 2 parts of clean sand, and 2 parts of crushed stone or gravel, ranging in size from ¼ inch to ½ inch. If, however, no coarse aggregate is used, a 1:2½ or a 1:3 mixture of cement and coarse sand should be used.

The slab and pedestals are cast separately. In making the slab, first fill the mold uniformly to a depth of ¾ inch and then lay the reinforcing as indicated on the plate, having previously laid out and wired together at intersections the reinforcing to correspond with the dotted lines on the plate. On top of this place the remaining 2½ inches of concrete, which should be wet enough to require only slight tamping to flush water to the surface. Following this the mold may be shaken to cause the concrete to settle into corners. This top surface will be the top of the finished bench, therefore it will pay to use care in finishing it to as smooth a surface as possible. An edger is run around the inside of the form to give a rounded edge to the top of the slab.

General Notes:

Do not attempt to remove the form from the under side of slab for at least seven days; under favorable conditions, the sides of the form can be removed after forty-eight hours.

VII. Posts and Columns

1. Class-room Work.

(a) Concrete fence-post construction. Hitching posts; ornamental posts and columns.

References:

"Lessons in Concrete," No. 7.

United States Department of Agriculture Farmers' Bulletin No. 403.

General Notes:

Concrete posts have been constructed in a great variety of shapes—triangular, round, square, half-round, etc. The rectangular post commonly used by farmers is 7 feet long, 5 by 5 inches at the bottom, and tapers to 3 by 3 inches at the top. The length, 7 feet, permits placing 2½ feet of the post in the ground. Some prefer an 8-foot post.

(b) Corner and gate-posts; size and bracing.

References:

Same as under (a).

General Notes:

Concrete corner, end, and gate-posts should be square, and the sides should be not less than 12 inches wide, and the post should be placed from 3 feet 6 inches to 4 feet in the ground.

2. Form Work.

(a) Construction of forms for fence line posts (two designs); corner and gate-posts (two designs); hitching-posts and lighting standards.

3. Concrete Work.

   (a) Construction of forms for line posts; concrete base for steel and wooden posts; gate-posts; hitching-posts; lighting standards.

VIII. Foundations and Piers

1. Class-room Work.

   (a) Laying out, and excavating for, foundations.

   References:

   "Lessons in Concrete," No. 5.

   Bulletin No. 26, "Concrete in the Country."

   General Notes:

   In preparing to erect any rectangular structure a base line should first be established, and from it the several corners be located by accurate measurement at right angles, and then all measurements should be checked back to the base line. The depth of the excavation depends upon the height and character of the building, but should always go to solid earth and below frost line.

   (b) Forms for mass construction.

   References:

   Same as those under (a).

   General Notes:

   Forms for piers and machinery foundations are constructed in substantially the same manner as are forms for regular building foundations.

   (c) Repairing old barn foundations.

   References:

   See those under (a).

   General Notes:

   Foundations which are laid up in mortar may disintegrate and crumble, and this condition frequently exists in buildings which are otherwise in a fair state of preservation and well worth saving. If the foundation wall has not gone to pieces, a large portion of it can often be left in position and boxed in with concrete. If that part of the foundation below ground is left in good condition, it may be capped with concrete. It will, of course, be necessary to take the load of the building off the foundation temporarily, so that the crumbled portions may be removed and the new concrete be given a chance to harden. It may also be necessary to replace old sills and splice posts.

2. Form Work.

   (a) Forms for foundations (three types).

   (b) Forms for piers.

Reference:

Bulletin No. 26, "Concrete in the Country."

3. Concrete Work.
   (a) Construction of a section of foundation wall by the students. (*Note.*—The students will take a greater interest in the work if it is possible to go out and do a little practical concreting around the school grounds or in the vicinity, such as building or repairing a piece of sidewalk, foundation wall, etc.)

IX. Ornamental Work

1. Class-room Work.
   (a) Core making; shaping of reinforcement; the use of clay molds; plaster and glue molds and cores; coloring and finishing surfaces.

   References:

   Ralph Davison's book, "Concrete Pottery and Garden Furniture."

   "Lessons in Concrete," No. 6, The Surface Finish of Concrete.

   General Notes:

   In case ornamental work is to be attempted, Ralph Davison's book should be obtained. This book takes up the subjects of plaster molds, glue molds, and wire forming in a simple manner.

Colored Surfaces

For artistic work it is better to depend upon selection and combination of aggregates of various colors than upon any process of coloring by pigments. However, artificial coloring-matter, if used, should never exceed 8 per cent. of the weight of the cement, and should be mixed with dry cement before water is added. Nothing but mineral coloring-matter should be used, and the following table, taken from "Cement and Concrete," by L. C. Sabin, is generally accepted as the standard authority for amounts of different coloring materials required to produce certain shades:

COLORED MORTARS

Colors Given to Portland Cement Mortars Containing Two Parts River Sand to One Cement

Dry material used	Weight of Coloring-matter Per Bag of Cement			
	½ pound	1 pound	2 pounds	4 pounds
Lamp-black	Light slate.	Light gray.	Blue gray.	Dark-blue slate.
Prussian blue	Light green slate.	Light blue slate.	Blue slate.	Bright blue slate.
Ultramarine blue	..	Light blue slate.	Blue slate.	Bright blue slate.
Yellow ocher	Light green.	..	..	Light buff.
Burnt umber	Light pinkish slate.	Pinkish slate.	Dull lavender pink.	Chocolate.
Venetian red	Slate, pink tinge.	Bright pinkish slate.	Light dull pink.	Dull pink.
Chattanooga iron ore	Light pinkish slate.	Dull pink.	Light terra-cotta.	Light brick red.
Red iron ore	Pinkish slate.	Dull pink.	Terra-cotta.	Light brick.

2. Form Work.
   (a) Construction of ornamental molds and cores for flower-boxes, straight line vases, round fern jars, circular vases, with and without a handle, urns, drinking fountains, bird baths, animal drinking tanks, etc.
3. Concrete Work.
   (a) Construction of exercises selected from above. (*Note.*—By this time the students should be sufficiently familiar with the work to plan original exercises of their own. The instructor should encourage originality, and also give the students opportunity to make some preferred exercise.)

Exercise 8

The Construction of a Concrete Flower-box

(Plate No. 14)

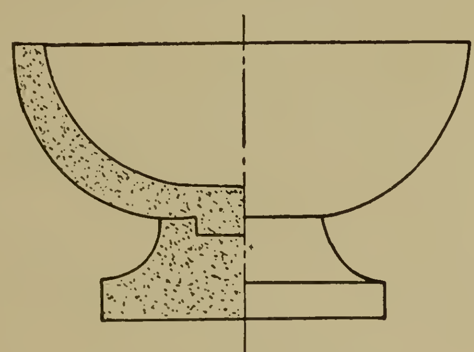
The long window-box shown in Plate No. 14 should be made of 1 part cement and two parts of clean sand, and will take approximately 32 pounds of cement and ¾ cubic foot of sand. The student should have little trouble in making the form if the directions shown on the plates are closely followed.

After the surfaces of the form that are to come in contact with the concrete have been well oiled, the form should be assembled. Reinforcing should consist of ½-inch galvanized square-mesh wire, which is placed in position by making a basket that, when put in place in the form, will be ½ inch from the inside surface of the form. This basket can be held in place by slipping blocks between it and the inside form, these to be removed after the concrete has been deposited up to within about three inches of the top of form.

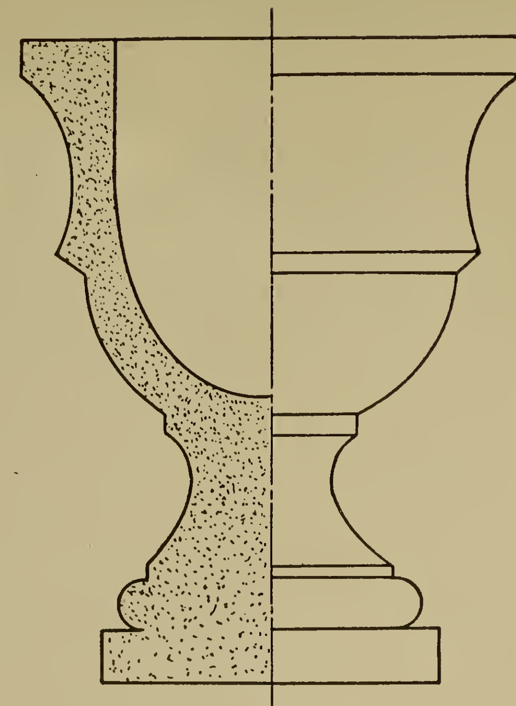
Sand should be measured out accurately and placed upon the mixing board in a thin layer. The cement is then distributed over the sand and the two are mixed until the color is uniform. Water should be added slowly from a sprinkling can until the mixture is thin enough so that it will flow readily into and fill all parts of the form. A trowel, or a thin, flat stick with a chisel end, should be worked up and down along the inside of the form so as to force the coarse particles of the mixture away from the surface.

It is not advisable to remove forms until the flower-box has been in the mold for at least twenty-four hours, and a great deal of care should be taken when removing the form so as not to damage the green concrete. After removing the form the outside surface should be brushed with a stiff brush or an old broom; the flower-box should then be allowed to air-dry possibly two or three hours, but be kept from drying out too rapidly; never place in the sunlight. The box should then be placed in water and allowed to soak for three or four days. A very smooth surface can be obtained by sprinkling dry cement over the wet surface after removing from the water and rubbing the cement in with a scrubbing-brush or with a block of cork.

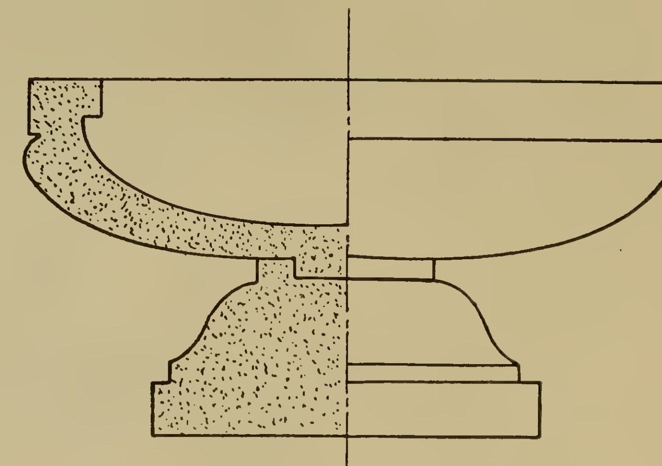
(The above directions will also apply in constructing the smaller flower-box on Plate No. 14.)



BOWL - 26 INCHES
BASE - 16 INCHES
HEIGHT - 15½ INCHES



BOWL - 28 INCHES
BASE - 19 INCHES
HEIGHT - 36 INCHES



BOWL - 36 INCHES
BASE - 22 INCHES
HEIGHT - 20 INCHES

PLATE 13.—DESIGN FOR CONCRETE URNS.

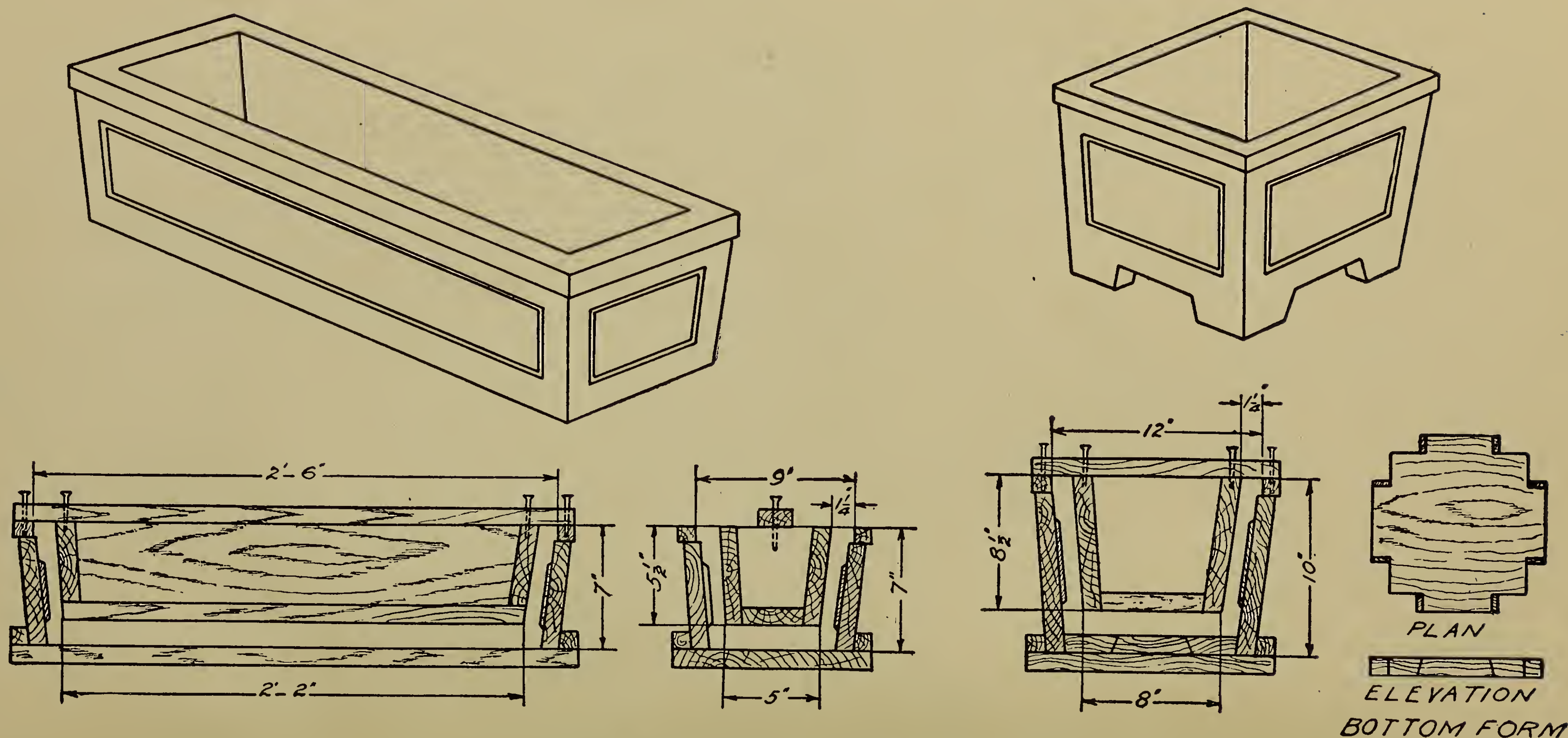


Plate 14.—Concrete Flower-boxes.

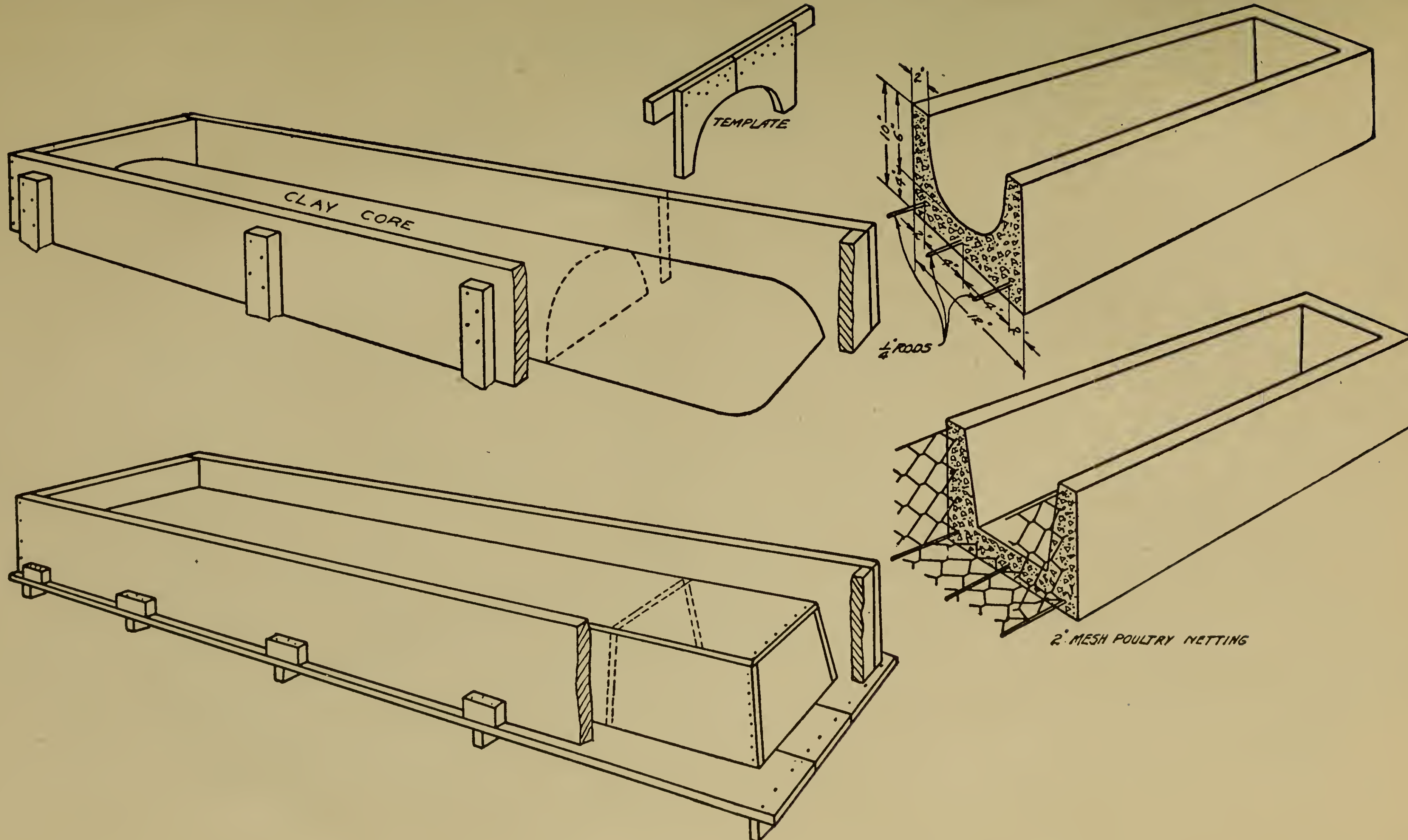


PLATE 15.—DETAILS OF CONCRETE TROUGH CONSTRUCTION.

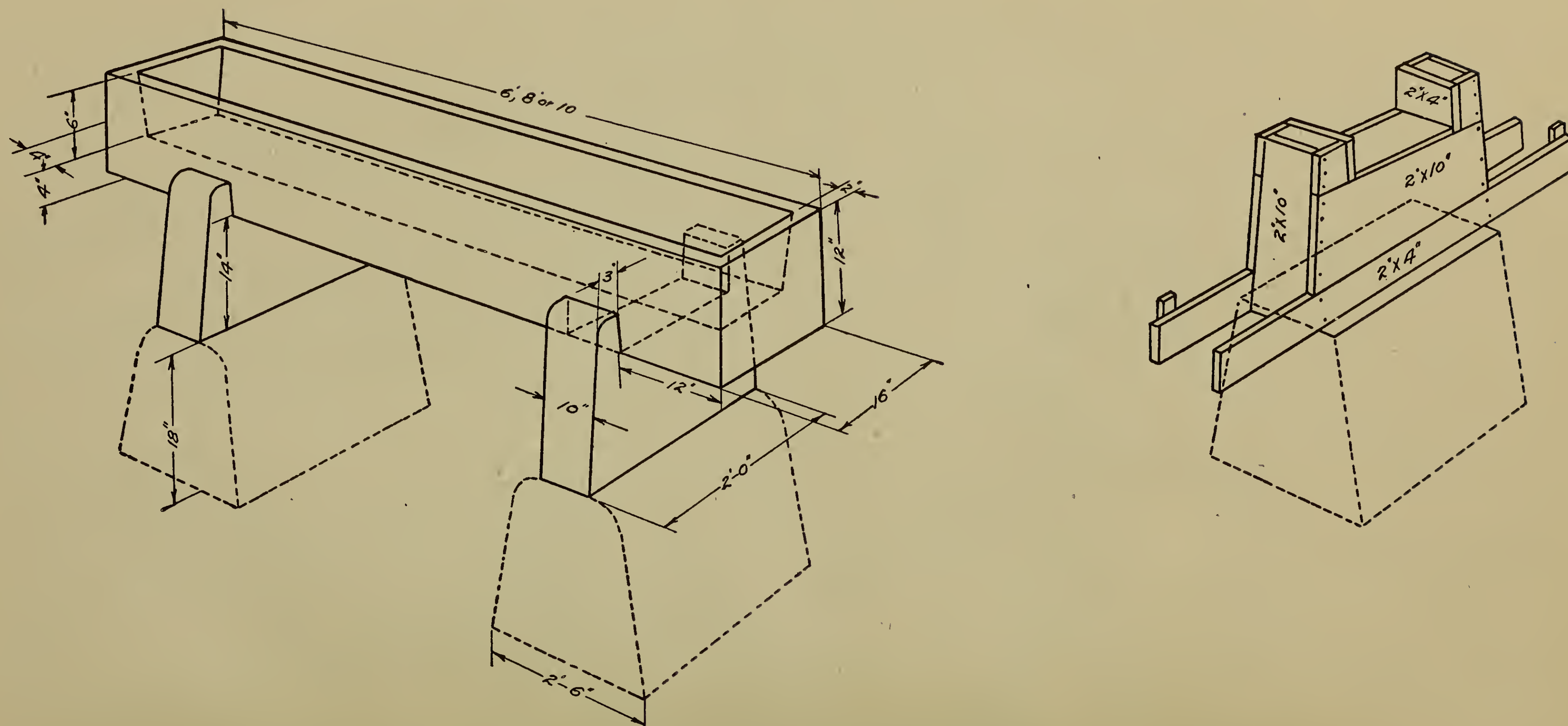


Plate 16.—Small Concrete Watering Trough.

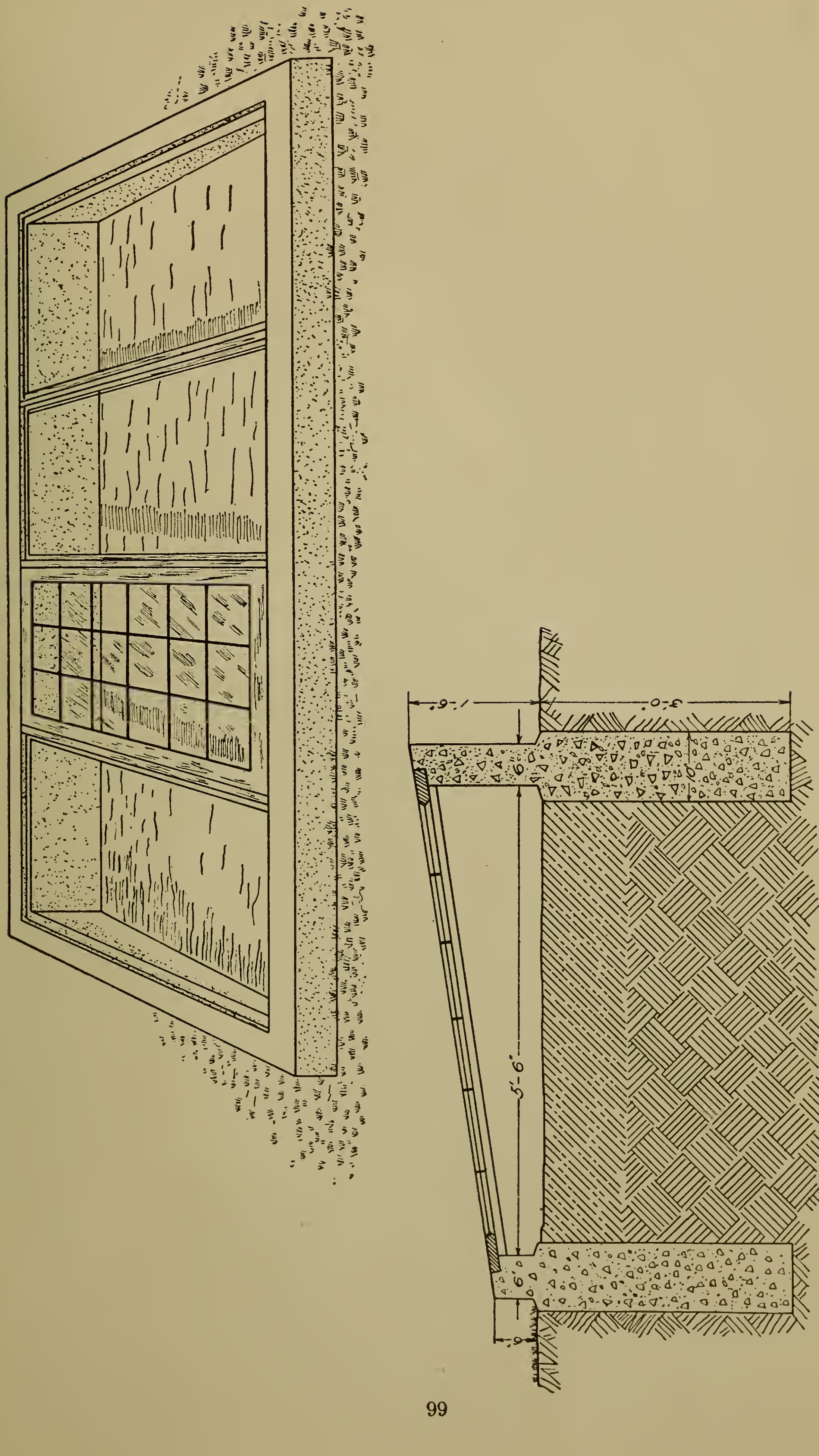


PLATE 17.—CONCRETE HOTBED.